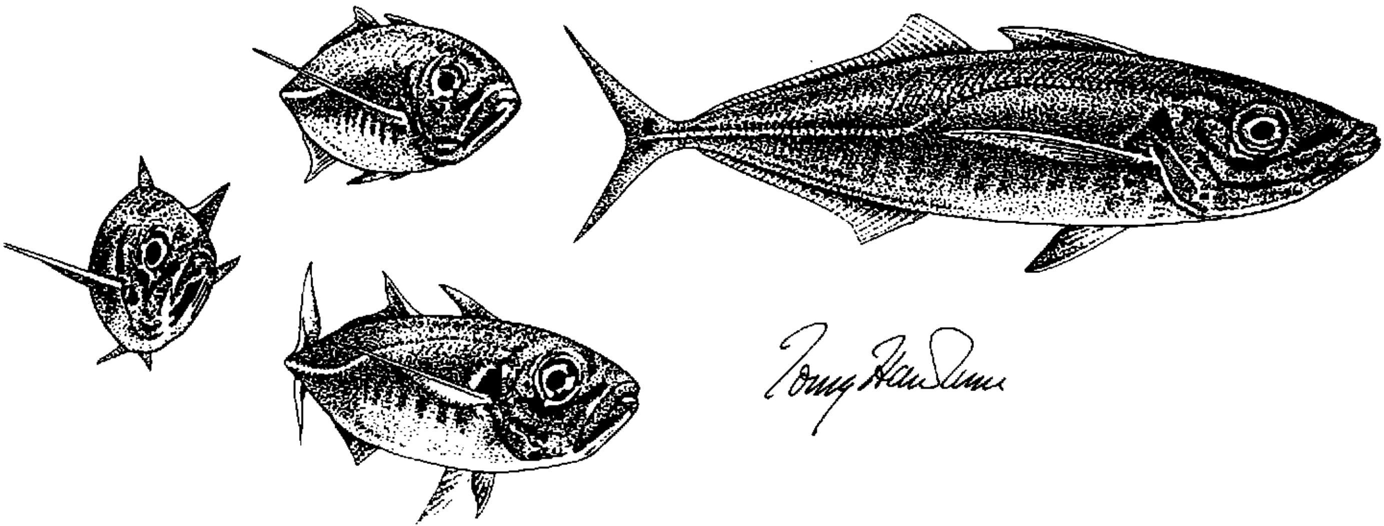
Living Resources Committee | ICES CM 1999/G:16

REVISED

REPORT OF THE

HORSE MACKEREL OTOLITH WORKSHOP

Lowestoft, United Kingdom
15-19 January 1999



International Council for the Exploration of the Sea

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1 INTRODUCTION

1.1 Terms of Reference

At the ICES Annual Science Conference in Lisbon (Portugal) in September 1998 it was decided (C. Res. 1998/2:59) that a Horse Mackerel Otolith Workshop [WKHMO] (Chair: A. Eltink, the Netherlands) will be held in Lowestoft, UK from 15–19 January 1999 to:

a) improve the quality of horse mackerel age readings;

b) prepare a synopsis of the biology of the species (stocks, migrations, spawning, feeding, maturity, growth, etc.);

c) prepare an overview on how the ageing technique was validated;

d) review the sample processing methods;

e) prepare a manual for age reading (date of birth, interpretation of rings and edges, guidelines on how the best ageings can be achieved, etc.); with the objective of improving expertise and training and ensuring that new age readers are well calibrated against experienced age readers in other institutes;

f) compile available information on when translucent and opaque otolith edge structures occur by month and by age group for both western and southern horse mackerel stocks;

g) carry out an exercise to estimate the precision, accuracy and bias from an age reading comparison on otoliths of known age to be carried out at the end of the workshop to demonstrate the improvements;

h) make recommendations on how to improve the age reading quality;

i) determine to what extent age-reading errors affect stock assessments of horse mackerel;

j) obtain a peer review of the Workshop report from the appropriate Assessment Working Groups prior to the 1999 Annual Science Conference.

Financial support for the meeting was obtained from the European Union (MAC/09/98).

1.2 Objectives of this Workshop

A validation of the ageing reading method is essential and a short review on how this was achieved should be given.

At the beginning of the Workshop the terms accuracy, precision, bias, average age, modal age and agreement, etc. should be explained to the otolith readers. The results of the 1996 Horse Mackerel Otolith Exchange should be discussed and explanations should be given to the otolith readers on how to improve their age reading techniques.

The processing methods for the otoliths have to be described and discussed for the different fishery institutes, because these methods determine what quality of age readings can be achieved.

A synopsis of the horse mackerel biology should be presented to indicate how the horse mackerel (*Trachurus trachurus* L.) is distributed in the northeast Atlantic area, how the three stocks are distributed, on what basis these stocks are separated, at what time adult fish migrate from overwintering area to spawning area, to feeding area and back to overwintering area, when the periods of pre-spawning / spawning and of feeding / non-feeding are, how the juvenile fish are distributed over time in these areas, etc. Compiled information on the monthly deposition of translucent and opaque material on the otolith edge should be available by age group to all otolith readers, because the time of the opaque and translucent material deposition is dependent on the age of the fish and the time of the year.

This biological background of the horse mackerel should be known for correct interpretation of the ring structures and otolith edges. Once this biology is understood by the otolith readers, training in otolith reading can be started by using only 'known' age otoliths with only translucent edges (exclusively caught in the first half of the year). Then the age readings are not dependent on the otolith edge interpretations and therefore differences in age readings can only be related to the interpretations of the rings (annuli) within the otoliths. The results can be discussed immediately after reading in order to correct the ageing techniques of the individual otolith readers.

Once the interpretation of the inner rings does not cause problems in the interpretation a start can be made with the training in otolith reading by using only 'known' age otoliths with a mixture of translucent and opaque edges (exclusively caught in the second half of the year). Then the age readings become dependent on both the otolith edge interpretations and the interpretations of the rings within the otoliths. The results can be discussed immediately after reading in order to correct the ageing techniques of all individual otolith readers.

This training is very important to remove the bias in the age readings of especially the older fish (improving the accuracy). However, in addition special attention will be paid to the improvement of the precision (reducing the variation in the age readings). During the otolith exchange it became apparent that some readers were able to achieve a high precision. It is therefore important that they try to explain to other readers how they are able to achieve this.

A manual on horse mackerel age reading will be prepared, which will provide the guide-lines to experienced and inexperienced otolith readers on how to read and interpret the rings and the edges of the horse mackerel otoliths in order to achieve a high accuracy and a high precision. Recommendations will be given on how the quality of the age readings can be improved.

At the end of the Workshop it will be tested how well all readers can carry out age readings on horse mackerel otoliths. The Workshop will provide information on the bias, accuracy and precision of the age readings by age group for each individual otolith reader and for the whole group of otolith readers combined. Furthermore the changes in bias, accuracy and precision compared to the beginning of the workshop will be given.

Errors in the age readings affect the stock assessments of horse mackerel. It should be determined to what extent these assessments are affected.

1.3 Participation

The Workshop met in Lowestoft from 15-19 January 1999 with the following participants:

Participants taking part in the comparative age determinations:

Pablo Abaunza	#	*	Spain
Elizabeth Barnwall		*	Ireland
Astrid Conrad		*	Germany
Ana Maria Costa		**	Portugal
Bram Couperus			Netherlands
Gudrun Gentschow			Germany
Helga A. Gill	#	*	Norway
Mike Kerstan		**	South Africa
Eugene Mullins			Ireland
Quena Peleteiro			Spain
IÒaki Rico		*	Spain (Basque Country)
Simon Rijs	#	*	Netherlands
Luisa Silveiro	#	*	Portugal
Aage Thaarup			Denmark
Terry Watson (part-time)			UK (England)
Phil Welsby			UK (England)

Other participants:

Guus Eltink (Chair)	Netherlands
Christopher Zimmermann	Germany

* indicates which otolith readers participated in the 1996 Horse Mackerel Otolith Exchange.

** indicates which otolith readers read one otolith set of the otolith exchange after publication of the otolith exchange report Eltink (1997).

# indicates which otolith readers provided horse mackerel age reading data to the ICES Mackerel, Horse Mackerel, Sardine and Anchovy Assessment Working Group in 1998.

1.4 Introduction

The aim of the age determination workshop is to calibrate the age reading method of the otolith readers. An accurate and consistent identification of annuli and a reduction of reader subjectivity and bias to the very minimum have been the aim of previous otolith exchange programs (Eltink, 1985; Borges, 1989, Eltink, 1997) and otolith reading workshops held in Lowestoft and Lisbon in 1987 and 1990, respectively (Anon., 1987; ICES, 1991). The objectives of this workshop are extensively described in Section 1.2.

2 GENERAL

2.1 Synopsis on the biology of horse mackerel in European waters

Introduction

The horse mackerel (*Trachurus trachurus* and *T. trachurus capensis*) is a member of the large carangid family, which includes many important commercial species worldwide. The name of the horse mackerel is misleading, as the true mackerel-like fishes such as tunas or bonitos belong to the scombrid family. Horse mackerel is a schooling species, caught mainly with pelagic nets, but close to the sea floor. *T. trachurus* is commonly found from the waters off West Africa/Cape Verde Islands to the Norwegian Sea, including Iceland, as well as in the Mediterranean and Black Sea. It is the most northerly representative of the trachurid sub-family, which is widely distributed in the world's seas and often supports important fisheries.

Species identification

Three different species of the *Trachurus* genus are found together and are commercially exploited in parts of the ICES Sub-area VIII and Division IXa: *T. trachurus, T. mediterraneus* and *T. picturatus.* In ICES Sub-areas II-VII only *T. trachurus* occurs. Studies on genetic differentiation showed three clear groups corresponding to each species of *Trachurus* with no intermediate principal component scores, excluding the possibility of hybrids between the species (ICES, 1998). In ICES Sub-areas II-VII only *T. trachurus* occurs.

The most obvious feature to distinguish these three species is the length of the accessory (dorsal) lateral line (Nümann, 1959). In *T. trachurus*, the accessory lateral line extends to below the soft dorsal rays 23–31, in *T. mediterraneus* it ends below the 8th dorsal spine to the 3rd soft ray (Figure 2.1). *T. picturatus* shows an intermediate length of the accessory lateral line, ending below soft dorsal rays 5–10. Other features used for species discrimination are the shape, number and diameter of the scales of the curved lateral line, and the number of gill rakers.

Stock definition

It is assumed that there are three distinct spawning populations of *T. trachurus* in the northeast Atlantic (section 4.3 of ICES, 1998):

- the southern horse mackerel around the Iberian peninsula;
- the western horse mackerel in the Norwegian Sea, northern North Sea, western part of Skagerrak, west and south off the British Isles, western Channel and west off France;
- the North Sea horse mackerel, mainly restricted to the central and southern North Sea, eastern part of Skagerrak, Kattegat and eastern English Channel.

Earlier stock discrimination studies have not provided firm evidence for the existence of true horse mackerel stocks (Polonsky & Baydalinov, 1964, Nazarov, 1976 cit. in ICES, 1992). However, one genetic study provided a significant separation between a southern and a northern component (Nevedov *et al.*, 1978). The southern stock is commonly mixed with *T. mediterraneus* (Polonsky & Baydalinov, 1964). ICES (1992) concluded from circumstantial evidence that there is little exchange between the southern and the western units. These could therefore be regarded as stocks. This separation is also based on the observed egg distributions and the spatial and temporal distribution of the fishery. The 1995 (ICES, 1996) and 1998 egg surveys covered both the southern area and western area. Spawning areas have been defined for the North Sea by a series of egg surveys from 1988–1991 (Eltink, 1990, 1991 and 1992). However, there are transition zones with low egg abundance between the main spawning areas of the western and the southern as well as the western and North Sea area (ICES, 1996), indicating no clear separation of stocks.

Attempts to separate stocks have included discriminative measurements of the length of otoliths at age 1 (L_1) (Marecos, 1986). A tagging experiment carried out off Spain in 1997 did not result in any returns. As a result of this, and a lack of any newer conclusive evidence to indicate that the Western and Southern stocks are independent units, a degree of uncertainty exists concerning the true identity of these stocks (ICES, 1992).

Kerstan (1991) found significant morphological differences between North Sea and Western stock members, at least when using age stratified samples. However, horse mackerel is a migratory species and the distribution of the Western and North Sea component overlap extensively during over-wintering in the western Channel. The overlap during summer feeding in the Skagerrak is relatively small (ICES, 1998).

Distribution

Shelf attachment is a predominant distributional pattern of horse mackerel. For the North Sea stock, Olsen (1983) gave a distribution close to the southern and eastern coast of the southern and central North Sea area. Western and Southern stock components are closely connected to the shelf contour, as demonstrated on a number of occasions (e.g., Dornheim, 1987; Macer, 1977; Dornheim & Kerstan, 1985; Eaton, 1989; Dornheim, 1993; Porteiro *et al.*, 1993) (Figure 2.2 and 2.3). Iversen *et al.* (1998) describe the effect of the influx of Atlantic water on the feeding migration of western horse mackerel to the northern North Sea.

Horse mackerel show distinct areas for spawning, feeding and over-wintering, what is most evident in the case of the western stock (Borges *et al.*, 1995). Migration might be mainly driven by water temperature. In autumn, at a temperature falling below ca. 10°C, *T. trachurus* retreat from the feeding areas in the southern Norwegian and the North Sea and migrate to the over-wintering areas further south. These are situated in the English Channel (Lockwood & Johnson, 1977, Macer, 1974 and 1977) and along the continental slope (Macer, 1977) in the Bay of Biscay and Celtic Sea (Eaton, 1983, Figure 2.3). In winter they form dense schools in deeper water. In spring the fish become far more dispersed (Polonsky, 1965) and migrate northward again with increasing water temperature (e.g., Chuksin and Nazarov, 1989). The North Sea component appears in April in the southern North Sea and reaches the western Jutland coast and southern Norway by August. Parts of the Western stock may reach Trondheim Fjord in July-August (ICES, 1998). Other parts of this component feed in areas west of Ireland or at the Bay of Biscay continental slopes. The Southern stock shows a large overlap between spawning and feeding areas. In fact, in the Cantabrian Sea and Galician waters, the horse mackerel population appears more stable and stationary than typically migratory although there are also variations of small magnitude (Villamor *et al.*, 1997).

Apparently, the water temperature of 8°C is the lower limit for horse mackerel which it avoids during over-wintering (Polonsky, 1965). Laboratory investigations have shown that they stop feeding at water temperatures below about 10°C (Herrmann, pers. comm.). Lozano Cabo (1952) gives optimal water temperatures of 19–23 °C, higher temperatures seem to be avoided.

Stock size

Southern and western horse mackerel stocks are assessed usually by VPA (Adapt or other variations) (e.g., ICES, 1998) and tuned with biomass estimates from egg surveys (e.g., ICES, 1996 and 1997). The stock size depends on (a) the stock definition, (b) recruitment and (c) the rate of exploitation. Nevertheless, with all caution it is possible to provide estimates of the order of magnitude of the stock or biomass size of an exploited but not severely overfished stock. The spawning stock biomass in Iberian waters, particular the southern continental shelf parts of the Bay of Biscay (**Southern** stock) is estimated by analytical methods (ICES, 1998) and by means of the egg production method (e.g., Walsh *et al.*, 1990, Franco *et al.*, 1993) and ranged recently between 200 and 265 thousand tonnes (ICES, 1998). Based on egg surveys, the size of the stock in the **North Sea** was estimated to be in the range of 220 - 250 thousand tonnes (Eltink, 1990, 1991 and 1992). However, undoubtedly the largest part of the spawning stock biomass is attributed to the **Western stock**. The stock size has been fluctuating throughout the past decades due to very unstable recruitment and changing levels of exploitation. The stock reached its maximum in 1988 with nearly 6.5 million tonnes and is now in the range of 1 to 1.5 million tonnes. Over the last 15 years, the stock was dominated by the extraordinarily strong 1982 year class. The 1982 cohort can be traced until it disappears in the 15+group (Figure 2.4). Accordingly, the fishing pressure on this stock increased drastically, with raising F's since the mid 80'ies. In spite of having an assessment, which is methodologically weak, it becomes clear that the stock is in a state of decline, which is indicated by the different methods.

Age and growth

Horse mackerel is a fairly long-lived species. The cohort analysis of ICES (1998) shows that the 1982 year class has been extraordinarily strong and can be identified for 15 years in the annual age compositions (Figure 2.4). Ages of nearly 40 have been reported. However, for assessment purposes the higher ages are not differentiated and summarised as 15+ ages.

Borges (1991) described the growth of horse mackerel by length frequency analysis of commercial catch data, disaggregated on a monthly scale. She described two cohorts recruiting to the fishery each year. Both cohorts grew into each other in the course of the first two years and were later on not distinguishable any more. Depending on the method employed (Battacharya or Shepherd) L_∞ was in the region of 40 to 50 cm TL with $K = 0.29$ and 0.14, respectively. Considerably larger horse mackerel were however observed in the field (e.g., 59 cm TL in Portuguese waters, Murta *et al.*, 1993).

The species *T. picturatus* seems to show a similar growth. Isidro (1990) found an L_∞ of 52.9 cm (fork length) for individuals from the Azores. For *T. mediterraneus*, Lucio (1996) provides a similar L_∞ (52.01 cm TL).

Length weight relationships (in cm and g)

Species	Author	Region	Coeff.	Exp. b	Comment
T. trachurus	Fariña Pérez (1983)	northwest of Spain	0.01291	2.8545	Total length
T. trachurus	Lucio & Martin (1989)	Bay of Biscay		3.061	Total length
T. trachurus	Borges & Gordo (1991)	Portugal	0.009224	2.957	Total length
T. trachurus	Arruda (1983)	Portugal (Matosinhos)	0.0199	2.885	Total length
T. trachurus	Arruda (1983)	Portugal (Peniche)	0.0173	2.927	Total length
T. trachurus	Arruda (1983)	Portugal (Portimão-Sagres)	0.0135	3.005	Total length
T. trachurus	Kerstan (1985)	West of UK	0.0044	3.141	Total length
T. picturatus	Isidro (1990)	Azores	0.00819	3.11	Fork length
T. mediterraneus	Lucio (1996)	Bay of Biscay		2.945	Total length
T. t. capensis	Geldenhuys (1973)	South Africa	0.01240	2.9028	Total length

Several authors have given v. Bertalanffy growth parameters for *T. trachurus* (Lucio, 1990; Kerstan, 1985; Fariña Pérez, 1983; Lourdes Marecos *et al.*, 1978; Trouvery, 1977; Nazarov, 1978). As these are highly dependent on ageing method and accuracy, which are currently regarded as uncertain, they are not displayed here.

Nutrition and feeding habits

For the North Sea stock, after spawning in summertime, the fat and energy content of horse mackerel is lowest (Sahrhage, 1970, Herrmann pers. comm.). In August and September the horse mackerel energy content rises rapidly, apparently as a result of extensive feeding. As mentioned earlier, feeding ceases as soon as the water temperature drops below 10°C (Herrmann, pers. comm.). At 8–9°C the fish stop feeding totally and leave the area for over-wintering. In spring, before spawning, the horse mackerel have only little fat reserves in the gut (Leloup and Gilis, 1964). In accordance to this, Polonsky (1965) found that the muscle fat content is lowest in March and highest in September.

According to these findings, one should expect the development of opaque zones in the otoliths during periods of extensive feeding, which enables fast growth and enhanced calcification. On the other hand, starving during winter, the energy consuming gonad development in winter/spring and the period of spawning will lead to a formation of the translucent zone.

Several investigations indicate that *T. trachurus* is a filter feeder, swimming at low but constant speed (see physiology section), mainly ingesting zooplankton (e.g., Ben Salem, 1988). In the Eastern part of the **North Sea** (off Jutland) horse mackerel were found to forage predominantly on fish (Dahl and Kirkegaard, 1987), with 0-group whiting being the most important prey item, followed by other gadoids and herring. More to the south invertebrates constituted the bulk of ingested food items. Of these, surprisingly few *Crangon crangon* were taken and by far more decapods and other undetermined crustaceans. No clear shift of prey fraction with size could be shown. However, a clear diurnal feeding pattern was observed, with highest food intake during midday.

Dahl and Kirkegaard (1986) also found a clear diurnal feeding rhythm in the eastern part of the North Sea, but with highest food intake during early morning and lowest ingestion rates during the night. In this work, a shift in prey preference with age was proven: Smaller individuals (< 20–24 cm) preyed mostly on crustaceans, gobies and haddock, while larger specimens shifted towards herring. Smaller fish did not forage on herring at all.

In the **English Channel** apparently adult horse mackerel were found to forage to nearly 70 % on crustaceans and only to 17 % on fish, with monthly varying proportions (Macer, 1977).

For the **Bay of Biscay**, Letaconnoux (1951) provided a description of the horse mackerel diet, noting possible seasonal differences. For specimens from the northwest of Spain, Lozano Cabo (1952) suggested that young specimens are planktophagous while adults are mainly ichthyophagous. These findings were supported by a recent work of Olaso *et al.* (*in press*) on the diet composition in the southern Bay of Biscay. They found seasonal differences: preying on crustaceans dominated during spring, while in autumn *T. trachurus* > 30 cm began to prey on fishes (blue whiting, gobiids, anchovy), which represented 45 % of the food volume in this size-range. They also described a diurnal feeding mode, with feeding maximum around noon in spring (for fish > 30 cm), and at sunrise in autumn.

In **Portuguese waters** (ICES Division IXa) horse mackerel fed mainly on zooplankton, especially euphausids and copepods. Only at greater sizes (> 19 cm TL) they also fed on fish and cephalopods (Murta *et al.*, 1993).

Reproduction and recruitment

The sex ratio at least in the southern stock is 1:1 if surveyed over a wider area. Deviations from this relationship may occur if investigations are spatially and temporally not wide enough (Abaunza *et al.*, 1995). For the southern stock the length at first maturity is about 21 cm for males and approximately 22 cm for females (Borges & Gordo, 1991, Abaunza *et al.*, 1995). Horse mackerel is a batch spawner (e.g., Borges *et al.*, 1993). A potential fecundity of 1557 eggs per gram female horse mackerel was determined for the conversion of egg production into biomass of western horse mackerel (Eltink and Vingerhoed, 1993; ICES, 1996).

The maturity cycle of horse mackerel of the **southern stock** (off the Portuguese coast) begins in December, attains a maximum in February with highest gonadosomatic index between February and April, and lowest values in July to October (Arruda, 1983).

Surveys on the egg production of horse mackerel were carried out repeatedly in the waters off Portugal up to the areas north of Shetlands for spawning stock biomass estimation, including the North Sea (ICES, 1996; Iversen *et al.*, 1989; Eltink, 1992). The spatial and temporal distribution of the spawning process is given e.g., by Lockwood and Johnson (1977; see also Figure 2.2). However, more recent egg surveys have shown that the size of the spawning area also extends to the west of Ireland and Scotland later in summer (ICES, 1997).

Recruitment in the southern area is monitored by means of young fish surveys (e.g., Borges, 1983, 1984, 1986, Sánchez *et al.*, 1991). As discussed earlier, the analysis of the recruitment of the western component showed that the 1982-year class has been extraordinarily strong. It is remarkable that this year class was apparently not able to produce any larger recruitment. This accounts for the hypothesis that the stock recruitment for this stock is independent of parental stock size. Recruitment success could be primarily determined by hydrographic factors or feeding conditions of larvae and young fish. By contrast, it can also be argued that the low recruitment observed throughout the recent 15 years is the normal level of reproduction and the 1982 year class represents a freak reproduction success, which should not be the measure of successful recruitment.

Physiology and role in ecology

Horse mackerel is a predatory species, which is believed to consume considerable amounts of herring larvae and juveniles in the North Sea. It is regarded as one of the important predatory species in the North Sea ecosystem and the annual consumption is modeled by the Multispecies Virtual Population Analysis (MSVPA, Helgason & Gislason, 1979, Pope, 1979). The consumption is an input parameter for the MSVPA to determine natural mortality. To measure the consumption rate of horse mackerel, experiments are at present carried out at the University of Hamburg in the frame of an EU-project (*Consumption rates of predatory fish relevant for multispecies assessment in the North Sea and the Atlantic off Spain and Portugal*, CORMA). Two different methods are applied for the measurements and modeling of the consumption of horse mackerel, firstly by measuring the rate of gastric evacuation, and secondly by modeling bioenergetics. For the latter some physiological parameters are measured, such as the standard oxygen consumption for a weight range of 1.4 – 390 g, yielding a relationship of $VO_2 = 0.228 * WM^{0.725}$ (at 13°C) (Enders, 1998). Further analyses confirmed that the horse mackerel is a good swimmer. Only moderate increases in oxygen consumption were recorded at lower swimming speeds. This accounts for the hypothesis that for horse mackerel routine swimming is energetically not very costly, and that this species is adapted to swimming at a low but very constant speed.

2.2 Review of previous validations

Direct age validation has been carried out for the northeast Atlantic horse mackerel which confirmed that one opaque and one translucent zone constitute one annual growth zone (Kerstan and Waldron, 1995).

Tagging experiments could provide a direct validation, if immature fish of known age are tagged. However, no otoliths were available taken from recaptured tagged horse mackerel, which had been at liberty for a varying number of years. Such otoliths would be particularly helpful in providing an age validation for older fish.

Indirect age validations can be obtained from the comparison between ageings and the length-frequency distributions (Petersen, 1892). This method confirmed the ageings of the first years of life (up to age 4) (Letaconnoux, 1951).

Except in young fish, age determination presented considerable difficulties. At the Horse Mackerel Age Determination Workshop in Lowestoft, UK in 1987 ten otolith readers participated (Anon., 1987). Nine readers used the same and only one used another ageing technique. The results differed approximately by factor two. The ageing technique of the minority was likely to be the most accurate one based on the occurrence of annual year-marks that have been tested by following identifiable year classes through successive years age compositions (Eltink and Kuiter, 1989). Indications that a correct age determination method has been applied can be obtained by such an indirect validation technique. For example, in the catch in number of the western horse mackerel fishery (Figure 2.4), the extremely strong 1982 year class can be followed from 1984 to 1996.

2.3 Review of sample processing techniques by country

The following countries have experienced horse mackerel otolith readers and can, therefore, describe their processing technique:

The Netherlands

Otoliths are washed thoroughly immediately after collection in order to remove the organic material from the surface and subsequently stored dry in envelopes. One out of each pair of dried otoliths is broken transversely across the short axis through the nucleus. The fractured surface of the anterior half of the broken otolith is polished using an apparatus described by Bedford (1964). The rostrum is broken off and the polished part is then put with the convex side of the otolith upward on a thermostat regulated hot plate (temperature approximately 300°C). To clarify the ring structure these otoliths are carefully charred until darkish brown (Møller Christensen, 1964). The treated otolith is mounted on plasticine and submerged in 70 % alcohol together with the untreated whole otolith or, alternatively, the posterior half of the broken otolith (in the case of one missing otolith). Both are to be viewed and compared under a binocular microscope using a dark background and reflected light. Shading by means of an object moved between the light and the otolith improves the readability. Under reflected light, the opaque zones of fast growth appear white and the translucent zones of slow growth appear dark.

Spain

Otoliths are cleaned with the fingers immediately after removal to eliminate the remains of organic material. Whenever possible, for example aboard research vessels or in the laboratory, the otoliths are also washed with water. They are stored dry in envelopes with the information about the specimen (length, sex, etc.). One otolith of each pair is broken transversally and across that part where the nucleus is thought to be. This is easily made with the bare fingers or sometimes, when the otolith is very thick, with a knife, preferably a heavy, sharp-edged one. A little transversal mark is cut on the otolith with the knife, previous to applying the pressure knock, just to prevent slipping. The fractured surface of the posterior half of the broken otolith is polished with sandpaper moistened with water. Otoliths are placed with the convex side upwards, on a brass or galvanised iron plate. To burn the otoliths, the brass plate is placed over a Bunsen burner just until they become dark brown. The burnt half otolith is mounted in black plasticine, with the polished surface up, and submerged in 70 % alcohol, together with the untreated whole otolith. Both are read by means of a binocular microscope with reflected light. Moving the otolith carefully with the aid of tweezers improves the readability. Magnifications of 20–40x seem to be enough although, when the number of rings appears to be high a larger magnification is used. The reading of the translucent rings is usually done on either of the two edges of the *sulcus*. When the readings are finished, otoliths are stored in their corresponding envelopes.

Portugal

The otoliths are washed immediately after collection in order to remove the organic material from the surface and then stored dry in envelopes. One out of each pair of dried otoliths is broken transversely across the short axis through the nucleus. The fractured surface of the anterior half of the broken otolith is polished using the technique described by Bedford (1964). The polished part is then put with the *sulcus acusticus* upward on a hot plate, which is heated with a Bunsen burner until the otoliths get a brown coloration. Then, the otolith is mounted in plasticine and the broken surface is covered with immersion oil. The dark zones of slow growth are counted by means of a binocular microscope, using a dark background and reflected light.

Some time ago a reading technique with thymol was tested to improve the age readings. The storage procedure is the same as described above. The whole otolith of each pair of otoliths is submerged in a 0.01 % thymol solution (made with filtered and sterilised sea water) for 24 hours. Afterwards, the otoliths are washed in 70 % alcohol (submerged during 2 hours) and then placed in immersion oil for more than 24 hours. The otoliths are then observed (in the immersion oil) under a binocular microscope, with reflected light against a dark background, and the dark growth zones are counted in the external surface of the otolith. This experimental technique with thymol solution for whole otoliths is no longer in use due to unsatisfying results.

Norway

Otoliths are washed thoroughly immediately after collection in order to remove the organic material from the surface and subsequently stored dry in envelopes. One out of each pair of dried otoliths is broken transversely across the short axis through the nucleus. The fractured surface of the anterior half of the broken otolith is polished using wet sand paper, nr. P600. The rostrum is broken off and the polished part is then burnt over a bunsen flame for a few seconds while constantly in motion. To clarify the ring structure these otoliths are carefully charred until darkish brown (Møller Christensen, 1964). The thus treated otolith is mounted in plasticine and brushed with baby oil. The otolith is viewed by means of a binocular microscope using direct light, preferably an intensive cold-light source. Under reflected light, the opaque zones of fast growth appear white and the translucent zones of slow growth appear dark. The translucent rings in the burnt otolith are counted in the large ventral lobe near the *sulcus acusticus*.

Ireland, Germany and Denmark

Ireland, Germany and Denmark have not yet been reading horse mackerel otoliths routinely and therefore the descriptions of the otolith processing techniques are not included.

Comparison of processing techniques by country

The sampling processing techniques of the participating countries are approximately the same. Differences apply to the use of a bunsen burner with / without a brass plate versus a thermostat regulated plate and to the reading of otoliths submerged in alcohol or after brushing with oil.

2.4 Comparison of two otolith processing techniques

A first comparison of age determinations from thin sections and broken/burnt otoliths was presented in the report of the Horse Mackerel Otolith Reading Workshop in Lisbon in 1990 (ICES, 1991). The best age reader at that workshop was asked to age first 51 broken/burnt otoliths and later 51 thin slices of the same otoliths. An agreement of 67 % was reached. It was recommended that further research should be carried out on the sectioning technique to obtain thin slices of otoliths in order to improve the readability. However, no information on a comparison between the two techniques (thin slices versus broken/burnt sections) became available at this Workshop.

Therefore, the technique of reading thin slices with transmitted light was again discussed. Possible advantages of this technique are:

* the surface of the otolith section is 2-dimensional and therefore the images would be of a better quality;
* edges are clearly visible;
* the otoliths are much better protected;

* it is possible to maintain calibration and reference sets for many years.

The expected disadvantage is:

* that the preparation of the otoliths slices is more costly.

The major advantage of the present technique of reading both the broken/burnt and the whole otoliths is:

* no expensive equipment is required.

The disadvantages are:

* in cases of disagreement between the burnt section and the whole otolith, one has to decide between two readings;
* in most cases one has to focus, because the surface is not exactly 2-dimensional;
* otolith sets used as reference collection at the institutes and sets used for otolith exchanges and workshops become worn out and worthless after several readings (otoliths of the 1982 year class have an extremely high value for calibrating age readers).

The Workshop recommends that both the thin slicing and the broken/burnt preparation technique should be thoroughly compared before shifting to this new technique. Therefore, the Workshop recommends that the best otolith readers of this workshop read otoliths of the 1982 year class (of each fish one otolith prepared according to the slicing technique and the other according to the broken/burnt technique) in order to assess the differences between the two methods. Elizabeth Barnwall (IMR, Dublin, Ireland) will co-ordinate the comparison of both methods.

2.5 Collection of information on the proportion of otoliths with opaque edges

At the Horse Mackerel Otolith Reading Workshop in Lisbon in 1990 (ICES, 1991) a recommendation was made that all horse mackerel otolith readers should collect information on the number of otoliths having a translucent or opaque edge by month and by area.

From 1990 onwards Dutch, Portuguese and Spanish readers have collected information on the proportion of otoliths with an opaque edge by age group and by month (see figures 2.5 and 2.6). The Workshop agreed that in theory this information is valuable and could be of some help. However, during the reading sessions the decision of whether an otolith has an opaque edge or not, was very dependent on the individual readers and this information was therefore considered as too subjective for common use. The readers are encouraged to continue the collection of this information for their own purposes. However, the former recommendation to collect this information for common (international) use is herewith drawn back.

3 RESULTS FROM 1996 HORSE MACKEREL OTOLITH EXCHANGE

3.1 Participants in the otolith exchange

According to the report of the Horse Mackerel Otolith Exchange (Eltink, 1997) 7 otolith readers participated in the 1996 Exchange. These participants are indicated with an asterisk (*) in the list of participants of Section 1.3. However, Mike Kerstan, South-Africa and Ana Maria Costa, Portugal read otolith sets A and B, respectively, after publication of the report of the otolith exchange. The revised age reading comparisons will be included in this report.

3.2 Age readings compared to 'actual' and modal age

The age reading comparisons of otolith set A are revised and are presented in this report, because the ageing results of Mike Kerstan (reader 9) from South Africa are now included.

Horse Mackerel otolith set **A** contains otoliths of only the extremely strong 1982 year class. Therefore, there is a high probability that the originally estimated age is correct (see section 4.2) and can be assumed as 'actual' age. The edges of all otoliths are translucent, because they were sampled in the first half of the year. Age reading should be relatively simple by just counting the number of translucent rings. In this validation set A the comparisons are made to both 'actual' age (Tables 3.1 and 3.2; Figure 3.1) and modal age (Tables 3.3 and 3.4; Figure 3.2) in order to demonstrate the difference between both methods of analysis.

The errors in the age reading methods of the individual age readers and both the accuracy (percentage of agreement) and precision (coefficient of variation, CV) of the ageings by reader can be observed from comparisons that are made to 'actual' age (Table 3.2 and Figure 3.1). Readers 3–8 appear to underestimate the older ages, while reader 2 seems to overestimate all ages (especially ages 7–9). Reader 9 obtains the highest agreement (71 %) with the 'actualí age and reader 3 and 9 show the best precision (CV = 7 %). Precision ranges from 7–18 % CV and agreement to the 'actual' age from 22–71 %. The underestimation of the older ages (bias) in the ageings starts approximately at age 8 and increases with age. The bias reaches approximately one year at age 13 (for the whole group of readers).

However, when the age readings of set A are compared to modal age instead of 'actual' age, 5 out of 8 readers agree quite well to modal age (Tables 3.3 and 3.4; Figure 3.2). Five of the readers apply roughly the same ageing technique, because they have a high agreement in the modal age comparisons. These readers have a low agreement in the 'actual' age comparisons. This problem of underestimating ages is serious and should be solved as soon as possible e.g., by using otoliths of 'known' age (1982 year class) to train the readers counting the translucent rings in the correct way.

Figure 3.3 shows that the agreement with 'actual'age is much lower than with modal age for the age groups 6 and older. If there would be no bias, the comparisons to 'actual' age and modal age would be the same. If a bias in the age readings occurs, the comparison to modal age provides a too optimistic information regarding the agreement. In general the age reading comparisons to modal age should always be accompanied by some proof that there is no bias in the age readings (use of otoliths from tagged fish, etc.).

Horse Mackerel otolith set **B** contains otoliths of different year classes. The age readings can therefore only be compared to modal age. The data of the age reading comparisons of otolith set **B** are revised and presented in this report, because the ageing results of Ana Maria Costa (reader 9) from Portugal are now included (Tables 3.5 and 3.6; Figure 3.4). Precision ranges from 8–18 % CV. Agreement to modal age ranges from 35–71 %.

3.3 Problems on otolith edge interpretation

Otolith set B contained otoliths with only translucent edges, because they were sampled in the first half of the year. Age reading should be relatively simple by just counting the number of translucent rings. Set C contained otoliths with both translucent and opaque edges. If difficulties in age reading occur because of this effect, it should be noticeable by comparing age bias plots from set B and C (Eltink, 1997). Reader 1 had the highest agreement of 74 % with modal age in set B, but only 51 % in set C. Reader 3 had the highest agreement of 74 % in set C, but only 61 % in set B. For readers 1 and 3 the average ages differed approximately one year between sets B and C. The explanation for this is that some readers did have difficulties with interpretation of the translucent / opaque edges. Some readers changed their age reading method from set B to C in a such way that it affected the modal age and therefore changed the level of modal age by one year. The conclusion in the report of the 1996 Horse Mackerel Otolith Exchange (Eltink, 1997) was: ìThe outer edge problem in ageing horse mackerel otoliths should be solved as soon as possible. This could be done by the use of the 1982 year class otoliths (both with translucent and opaque edges). Discussions on how to read and interpret the ring structures could help to improve the precision and accuracy."

4 MATERIAL AND METHODS

4.1 Otolith sets available to this Workshop

Otolith set G

This training set contained 170 pairs of otoliths with translucent edges, taken from fish caught during February - April in ICES Sub-area VII (Table 5.1). Otoliths from this set have only translucent edges and are therefore relatively easy to read by counting the number of translucent rings. The 'actual' age of the sampled fish was between 3 and 13 ('actual' age is explained in section 4.2). By age group, 6 up to 23 pairs of otoliths were aged (Table 5.2).

Otolith set I

This training set contained 129 pairs of otoliths with both translucent and opaque edges, taken from fish caught during September - November in ICES Sub-area VII. These otoliths are more difficult to read compared to set G because of additional otolith edge interpretation (opaque ring formation occurs in the second half of the year). The 'actual' age of the sampled fish was between 1 and 12 ('actual' age is explained in section 4.2). Due to time constraints at the workshop the otolith readers aged only 70 pairs of otoliths (Table 5.3). By age group, 5 up to 8 pairs of otoliths were aged (Table 5.4).

Otolith set K

This set contained 153 pairs of otoliths with both translucent and opaque edges, taken from fish caught during January - April and September - November in ICES Sub-area VII (Table 6.1). It contained otoliths collected in the first half of the year, which are relatively easy to read, as well as otoliths collected in the second half of the year, which are more difficult to read because of the need of the interpretation of the otolith edge. The 'actual' age of the sampled fish was between 1 and 13 ('actual' age is explained in section 4.2). By age group, 3 up to 19 pairs of otoliths were aged (Table 6.2).

Otolith set G and I were used for training purposes. The results from the age reading comparison were presented to the otolith readers immediately after reading these sets to correct their ageing method. Based on this information they discussed the otoliths that caused large differences in age reading results. Otolith set K was read at the end of the workshop and was used to provide information on the changes in precision, accuracy and bias during the workshop.

4.2 Basic assumption for the otoliths of 'known' age

During the period 1985 - 1995 the 1982 year class has been extremely abundant in the international catches (Figure 2.4). Furthermore, the other year classes have been very weak, especially the adjacent 1981 and 1983 year classes. It should be noted that these adjacent year classes were also absent during the earlier years of collection (1984–1986). During this period the fish of the 1981 and 1993 year classes were young and relatively easy to age. It was assumed that during this period the ages have been estimated with a high accuracy and precision. When the year of catch is known and when the majority of the otoliths taken are of this 1982 year class, the age readings have a very high probability that they agree with the true age. Therefore these otoliths of the 1982 year class can be regarded as otoliths of 'known' or 'actual' age.

4.3 Age determination criteria

The following criteria for age determination were assumed prior to and during this Workshop:

1) Date of birth is assumed 1st of January, which is an artificial date to assign all fishes born in one spawning period to a certain year class (it refers to a management reference year, if the date differs from the 1st of January).

2) One opaque and one translucent ring constitute an annual growth zone.

4.4 Analysis of the age readings

At this Workshop a lot more otolith readers, most of them inexperienced, participated than in the 1996 Horse Mackerel Otolith Exchange (see section 1.3).

All otolith sets (G, I and K) were regarded to contain otoliths of 'known' age or 'actual' age (see Section 4.2). Errors in the ageing method of an otolith reader can be detected from a comparison between his age readings and the 'actual' age.

For each set of otoliths the following analysis took place. An Excel spreadsheet was created which allows an analysis of the age readings of the otolith sets over an age range 0–15. The average age is estimated from the readings of each pair of otoliths. The difference between the highest and the lowest age is calculated. For each 'actual' age the mean age, the standard deviation (stdev), the coefficient of variation (CV) and the agreement to 'actual' age are calculated for each individual age reader and for all age readers combined. In the age bias plots the mean age recorded ± 2 standard deviations for each reader and all readers combined is plotted against the 'actual' age. This method of displaying ageing results is in accordance with the procedure recommended by the Workshop on Sampling Strategies for Age and Maturity (ICES, 1994).

4.5 Glossary

The following important terms are used in this report.

Validation The process of estimating the accuracy of an age estimation method. The concept of validation is one of degree and should not be considered in absolute terms. If the method involves counting zones, then part of the validation process involves confirming the temporal meaning of the zones being counted. Validation of an age estimation procedure indicates that the method is sound and based on fact (from Kalish *et al.*, 1995).

Accuracy The closeness of a measured or computed value to its true value (how close the estimated ages are to the true ages) (from Kalish *et al.*, 1995).

Precision The closeness of repeated measurements of the same quantity. For a measurement technique that is free of bias, precision implies accuracy (from Kalish *et al.*, 1995).

Bias is a systematical overestimation or underestimation of age. Bias is regarded as a serious error since fish are allocated to the wrong year classes.

Agreement The age readings that agree with other age readings or with modal / true age (in percentage). The agreement can be estimated for both individual age readers as well as for a group of readers. The same otolith reader can also estimate the agreement from repeated age readings. The agreement is dependent on the age and should therefore preferably be presented as agreement at age.

Annual Growth Zone (AGZ) A visible opaque and the adjacent translucent zone collectively interpreted as one year's growth. In otoliths from adult fish, the zones are readily identifiable as single rings. The outermost zone should be distinctly visible over the greater part of the otolith, irrespective of its relative width (from Anon., 1986).

False ring A ring which should not be interpreted as an annual ring, because it is laid down on the otolith as a result of a random, short-term fluctuation in some environmental parameter briefly affecting growth rate rather than a regular seasonal change in the environment (from Anon., 1986).

Annulus The translucent growth zone which forms the outer margin of each annual growth zone (AGZ) (from Anon., 1986).

5 AGE READING TRAINING USING OTOLITHS OF 'KNOWN' AGE

5.1 Otoliths with <u>translucent</u> edges

5.1.1 Results from training otolith set G

The age readings by reader, the 'actual' age, age difference in the ageings and the mean age are presented for each pair of otoliths in Table 5.1. Two general problems concerning the accuracy could be perceived during the evaluation of the reading results (Figure 5.1). Some readers over-estimated ages 4 to 9 (e.g., reader 10 and 13). All of them underestimated the ages from 11 years onwards. Reader 1 reached the lowest mean coefficient of variation (CV: 6 %) and the highest mean agreement with the 'actual' age (75 %) (Table 5.2). Reader 10 showed highest CV (19 %) and lowest accuracy (23 %). Apart from readers 1, 2 and 6, all readers had a high CV for younger ages up to age 6 and, correspondingly, a low accuracy for these. The accuracy was decreasing in older ages for all readers, but CV for ages older than 11 was relatively low for reader 3. The mean CV (precision) for all readers was calculated to be 14 %, ranging from 19 % for age 4 to 11 % for age 13. The mean agreement (accuracy) was calculated to be 81 % for age group 3 and generally decreasing to 11 % for age group 13. Highest age differences among a single pair of otoliths were found to be 6 for 5 fishes with an 'actual' age range of 7–12 (Table 5.1). Only one pair was read correctly and the same by all participants (age group 3), 11 pairs were determined with only a difference of one year (age groups 3–6).

5.1.2 Discussion on training otolith set G

The otoliths of set G were expected to have only translucent edges, because they were taken from fish caught in the first half of the year (January to April). This caused no difficulties in the otolith edge interpretations. Differences in the age readings can only be related to the interpretations of the rings within the otoliths.

All readers showed a bias in the age readings for the older ages (see Figure 5.1). The underestimation of ages started approximately at age 9 and increased to about nearly two years of underestimation at age 13. Some readers overestimated the ages 4, 5 and 6. The precision in ageing the younger fish is low as indicated by relatively high CV's for the younger age groups compared to the older age groups. Especially the inexperienced readers had problems with estimating the ages of younger fish.

The following agreements were reached after the discussions on the results of set G:

- readers should read both the burnt and the whole otolith of each pair;
- variable magnification should be available on the microscope to enhance clarity;
- if false or split rings are suspected to occur in the whole otoliths, the burnt sections have to be used for ageing;
- the measurement of annual growth zones will help to distinguish false rings;
- counting of rings should be done on the ventral side of the otolith next to the *sulcus acusticus.*

5.2 Otoliths with opaque and translucent edges

5.2.1 Results from training otolith set I

The age readings by reader, the 'actual' age, age difference in the ageings and the mean age are presented for each pair of otoliths in Table 5.3. From this set, 70 pairs of otoliths were chosen out of 129 available, in order to reduce the time needed for reading. Otolith edges were either opaque or translucent. One pair (#108) was lost during the reading procedure and had to be excluded for some of the readers.

Most of the readers tended to overestimate the younger ages (2–7). The underestimation of the age of fish was not as striking as for set G. CV's generally appeared to be higher. The lowest CV (highest precision) was again reached by reader 1 (8 %) and highest for readers 6, 7 and 8 (18 %). The highest accuracy was calculated for readers 3 and 12 (60 and 59 % respectively). The lowest for reader 4 (23 %). CV's were highest for the younger ages and decreased generally towards older ones. In contrast, only one reader assigned all 10 pairs of otoliths from 1- and 2-year old fishes to the 'actual' age. For all readers combined, the mean CV was highest for age 1 (39 %) and lowest for age 12 (10 %) without a clear trend in between. The mean agreements with 'actual' age ranged from 31 % (age 8) to 60 % (age 3).

For this set, not a single pair of otoliths was read correctly by all participants. Highest age differences were 8 years (for two 6 year old specimens), lowest one year difference for 9 pairs.

5.2.2 Discussion on training otolith set I

The otoliths of set I were expected to have both translucent and opaque edges, because they were taken from fish caught in the second half of the year (September - November). The differences in age readings can be related to both the interpretation of the edge of the otolith and the interpretations of the inner rings.

Difficulties in the interpretation of the edge of the otolith became apparent when the results of set G and I were compared. Often the mean age recorded by age reader differed by one year when set G and I were compared (Tables 5.1 and 5.3).

In younger fish some of the otoliths contained 'split' or 'false' rings. These were interpreted differently by the readers. One method to improve the interpretation is measuring each ring and to make comparisons with rings in otoliths, which do not have a 'split' or 'false' ring.

The discussion focused on when to count this year's increment. For the northeast Atlantic horse mackerel the spawning season has its peak in February (southern area) or in May/June (western area) (see Figure 2.2). The formation of the opaque zone starts after the spawning season.

Fish should be aged in the following way when otoliths have opaque edges: Otoliths sampled during the first half of the year with opaque edges must be assigned to an age group by counting all the translucent zones. If otoliths are sampled in the second half of the year the opaque edge must not be counted as a year's growth. This is especially true for older fish that often do not put down a translucent zone before some time into the 1st quarter.

Fish should be aged in the following way when otoliths have translucent edges: Otoliths sampled during the first half of the year with translucent edges must be assigned to an age group by counting all the translucent zones. If otoliths are sampled in the second half of the year the translucent edge must not be counted as a year's growth.

It is important that all readers take into account the time of opaque and translucent deposition in the respective areas of sampling when interpreting the edge of the otoliths, especially in the middle of the year, June - August.

6 COMPARATIVE AGE READINGS AT THE END OF THE WORKSHOP

6.1 Otoliths with opaque and translucent edges

6.1.1 Results from otolith set K

The age readings by reader, the 'actual' age, age difference in the ageings and the mean age are presented for each pair of otoliths in Table 6.1. This final Set K comprised 153 otoliths with translucent or opaque edges.

Figure 6.1 shows the accuracy and precision of the age readings per reader as seen for the training sets before. Again, there is a noticeable underestimation of older ages (> 9 years) for most of the readers. However, this general bias is weaker than it was for the training set G. Age determination at younger ages (< 3 years) was far more precise and accurate than for the earlier sets. An overestimation of middle ages occurred by only two readers (7 and 14). This is most likely caused by problems in identifying false rings.

The lowest precision among all readers was found in age groups up to 4 and declined towards older ages. It reaches more than 30 % CV for individual readers and 23 % in age groups 2 and 3 for the mean of all participants. By then, only reader 12 made an error in reading one otolith of a 1 year old fish (which led to a high CV due to the very small number of otoliths in this age group). Mean precision (CV) over all ages ranged between 8 % for reader 1 and 15 % for readers 7, 10, 13 and 14. The highest accuracy of 74 % was shown by reader 1, the lowest (37 %) by readers 7 and 8. The weighted mean for all readers was calculated to be 49 %, with highest values at age 1 (98 %) and declining to 29 % at ages 10–12.

The age differences among a single pair of otoliths were found to be up to 6 for 10 fishes with an 'actual' age range of 5–13 (Table 6.2). All participants read only 4 pairs correctly (up to age group 4).

6.1.2 Discussion on otolith set K

The otoliths of set K contained both translucent and opaque edges, because they were taken from fish caught in the first and second half of the year (January-May / September-November). The differences between age readings can be related to both the interpretation of the edge of the otolith and the interpretations of false rings as annuli in the first few annual growth zones. As stated before the 'actual' age of otoliths was assumed to be known (see Section 4.2).

Those readers who had improved accounted this to the added practice from the additional readings and the discussions following the previous sets G and I. However, the results showed that the translucent edge still created a problem for several readers. The equipment caused part of the problem. There was no consistent explanation for the bias observed in the older ages.

Two readers had problems in reading ages 5–8. During the discussions it became obvious that these readers were reading false rings as annuli. One method to improve the interpretation is measuring each ring and to make comparisons with rings in otoliths that do not have a 'split' or 'false' ring.

4The underestimation of ages of the older fish still remains problematic for most readers. It seems to be related to the quality of the transverse sections of the otoliths. For the estimation of the older fish one has to count the very narrow rings close to the *sulcus acusticus* in the transverse section of the broken/burnt otolith.

In the discussion it was pointed out that the reliability of the age readings might increase, if the quality of the examined material could be improved. The introduction of sliced transverse sections of the otoliths is expected to improve the precision and the accuracy and to reduce the bias. Probably it will also help to interpret the edge of the otolith.

7 EVALUATION

The best precision in age reading can be achieved when the otolith readers work with their own binoculars at their own institute having enough time available to do the job. During the 1996 horse mackerel otolith exchange (Eltink, 1997) the quality of the otoliths got gradually worse over time because of handling the otoliths. The last readers got therefore the worst quality of otoliths. During the workshop new sets of otoliths were used and the quality of the otoliths decreased over time, but remained the same for all readers, because they were all reading at the same time. There were, however, certainly quite large differences in the quality of the binoculars used at the workshop. But readers remained to use the same binocular in order to keep the ageing results of the three otoliths sets comparable. Time constraints, not working with their own binoculars and extensive age reading (up to 9 hours per day) with only short breaks were put forward as arguments that the precision might be worse compared to their usual way of age reading at their own institute.

Table 7.1 shows the changes in precision, accuracy and bias of the age readings of the individual otolith readers between the Horse Mackerel Otolith Exchange in 1996 (otolith set A) and the beginning of this workshop (otolith set G). There is no clear improvement in precision, accuracy and bias over this time period, except for otolith reader 5, who increased his accuracy (agreement to 'actual' age) from 22 % to 41 %.

At the end of the Workshop otolith set K was used to test if the readers had improved their ageing methods. Comparisons of results from set K to results from the training sets G and I provided information on the improvement due to discussions at the workshop. Table 7.2 shows the changes in the precision, accuracy and bias of the age reading methods of the individual otolith readers and all readers combined. During the workshop almost all age readers made good progress concerning precision and accuracy. Only reader 1, the most experienced one, had a slight decrease in precision and three readers showed no changes in their mean CVs (readers 7, 12 and 13). All participants except one (reader 3) have improved the agreement of their age determinations with the 'actual' age (accuracy). Readers 9 and 10 made a remarkable progress: they increased the mean accuracy of their age readings from 45 % to 58 % and 30 % to 45 %, respectively. At the same time, they reduced the coefficient of variation of the age determinations from 14 % to 9 % and 18 % to 15 %, respectively.

This generalised view becomes more complex when looking at the variation of values by age group (Figure 7.1). It is obvious that the increase in accuracy and precision occurred mostly for age groups 1 and 2 and the oldest ages. In age groups 1 and 2, the widest variation of both parameters was found among the readers at the beginning. The variation in precision and accuracy was reduced almost to zero for age group 1 by the end of the workshop. Over all, the accuracy and precision was improved for 8 out of 13 age groups.

However, the problem regarding the underestimation of the older ages (bias) appears not to be solved. Obviously, difficulties remained in recognising the annuli in the otoliths of older fish. This bias might be related to the quality of the broken/burnt transverse sections. The otolith processing technique of thin transverse sections might solve this problem in the future. Therefore, the Workshop recommended to test this new technique against the traditional broken/burnt method (see Section 2.4).

8 EFFECT OF AGE READING ERRORS ON THE ASSESSMENTS

According to the terms of reference (see section 1.1, item i), the effect of age reading errors on the assessment of horse mackerel stocks should be estimated. However, the information on the precision and the accuracy of the age readings from those otolith readers, who will provide the catch in numbers at age of horse mackerel to the ICES Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (MHSA-WG), became only available at the end of the workshop meeting. This term of reference could not be completed because of a lack of time at the end of the Workshop. Furthermore, this group was not regarded to be the right one to discuss and assess the effect of age reading errors on the assessment. The chair of the Horse Mackerel Otolith Workshop (Guus Eltink, Netherlands) addressed this specific term of reference after the Workshop meeting in an evaluation that is attached as an addendum to this report "The effects of age reading errors on the assessment of horse mackerel" (ICES CM 1999/G:16 Addendum)

9 MANUAL ON HORSE MACKEREL OTOLITH READING

OTOLITH EXAMINATION

The present age determination technique utilises whole and broken/burnt otoliths. When whole otoliths are used, annuli are counted on the lateral side of the whole otolith (see Figures 9.1 and 9.2). Experienced readers may produce consistently accurate and sufficiently precise readings up to ages of 5–8 years. However, the age derived from the examination of the lateral side of a whole otolith has to correspond to the age determined in a transverse broken/burnt section of the same specimen.

The use of broken/burnt transverse sections when ageing otoliths older than 6–8 years is mandatory. With increasing age otoliths grow in thickness and discontinue increment deposition in both the anterior and posterior directions. Therefore, the use of whole otoliths as the only source of age information is bound to produce a serious bias, resulting in a general underestimation of the longevity of the species.

Otoliths should be put in 70 % alcohol and be viewed with a stereo dissecting microscope allowing for adjustable magnification. The examination method is dependent on the preparation technique. Otoliths of younger fish should be viewed with lower magnification because false rings may confuse inexperienced readers. Otoliths of older fish should be viewed with increased magnification.

Whole otoliths

Whole otoliths must not be mounted or embedded prior to the examination because it may be necessary to lift them up and to view them from different angles. Whole otoliths should preferably be viewed under reflected light against a black background. The direction of the light relative to the otolith surface also needs to be varied. Therefore, the use of a versatile fiber optic light source is recommended. Under reflected light, the opaque zones appear white and the translucent zones dark. The initial magnification of about 15x suffices to read otoliths of up to 6 years of age. Older otoliths display much narrower annual growth zones (AGZs) which necessitate a higher magnification of at least 25x. The magnification should always be adapted in such a way that all annuli can be identified unambiguously. Whole and untreated otoliths may also be viewed in transmitted light. The opaque zones look dense and grey or brownish in transmitted light. The translucent zones appear to be translucent and/or white, depending on the age and thickness of the otolith. This method of viewing is not recommended for older otoliths exceeding 4–5 years of age.

Broken/burnt otoliths

The broken/burnt transverse sections are viewed under reflected light like whole otoliths. The initial magnification of 25x may only suffice to age otoliths of 1–3 years of age. Older and thicker otoliths should to be viewed at magnifications of 30–50x. The optimal magnification depends on the individual specimen viewed and should be adapted accordingly. Horizontal illumination of the sections with the light source being just above surface level or at angles of 10–30∞ improves the contrasts between opaque and translucent zones. Selective shading will enhance the contrasts between opaque and translucent zones even further. Under reflected light, the opaque zones of untreated otoliths appear white and the translucent zones brownish or brown, depending on the degree of charring.

ANNULUS IDENTIFICATION

It is commonly agreed on that one opaque and one translucent zone constitute an annual growth zone (AGZ) in horse mackerel otoliths. Although there is a number of exceptions to this rule (Fariña Perez, 1983; Arruda, 1987; Hatanaka & Kawahara, 1985; Wysokinski, 1985; Anon., 1986; Shcherbich, 1988 and 1992; Kerstan, 1995), this assumption may hold for the majority of the otoliths collected from the northeast Atlantic horse mackerel (Kerstan and Waldron, 1995). In the following, **an annulus**, by definition, **is synonymous with the translucent growth zone which forms the outer margin of each AGZ**. It is essential that annuli are identified consistently, checking for the same criteria in all otoliths. These criteria have to be applied standardly, regardless of whether they may prove useful or not in all of the whole and broken/burnt otoliths examined:

a) An annulus should be traceable on the whole otolith or the section, with the exception of the dorso-medial surface of the rostrum. In a section, problems may arise in the area of *the sulcus acusticus* and the dorso-medial direction on the medial side.

b) An annulus is characterised by the brightest contrast between the preceding translucent and the subsequent opaque zone deposited in the following year.

c) In the postrostrum of some of the otoliths the identification of an annulus may be enhanced by a more or less marked surface protrusion (Kerstan, 1985) which builds up as soon as the stacked translucent increments in the annulus are capped by newly deposited otolith material in the following growing season.

d) The opaque material deposited over or on the annulus in the following year appears slightly denser and more yellowish than the normally deposited opaque material.

e) In the rostral tip, an annulus may be marked by a clearly visible protrusion caused by material capped over or stacked on it at the beginning of the next growing season. Double growth zones may show two of these protrusions within one AGZ. However, the protrusion near the false ring is usually smaller than the protrusion next to the annulus.

f) In general, the widths of consecutive annual growth zones should decrease with increasing age.

In some cases, both the otolith section and the entire otolith may show additional translucent rings that resemble annuli, although they are false rings. Counting each of these well visible translucent rings will result in an overestimation of the age. To avoid wrong year class assignments the translucent rings should be measured. These measurements should be compared to the measurements derived from true annuli. If only every second measurement in an otolith corresponds, more or less, to a measurement of an annulus it is obvious that the recently measured specimen contains double growth zones in each AGZ. It is recommended here to establish a set of reference measurements for true annuli and to always compare ambiguous specimens to the reference measurements.

In case of doubt, when the readings of the whole otolith differ from the readings of the broken/burnt section, the readings from the broken/burnt section should always be preferred.

Fish should be aged in the following way when otoliths have <u>opaque edges</u>: Otoliths sampled during the first half of the year with opaque edges must be assigned to an age group by counting all the translucent zones. If otoliths are sampled in the second half of the year the opaque edge must not be counted as a year's growth. This is especially true for older fish that often do not put down a translucent zone before some time into the 1st quarter.

Fish should be aged in the following way when otoliths have <u>translucent edges</u>: Otoliths sampled during the first half of the year with translucent edges must be assigned to an age group by counting all the translucent zones. If otoliths are sampled in the second half of the year the translucent edge must not be counted as a year's growth.

<u>READER'S PRECISION AND DETECTION OF CHANGES OVER TIME</u>

Each age reader passes through various stages of experience during his/her assignments. Consequently, both the accuracy and the precision of the reader will increase when the experience of the reader increases. This may lead to a ëdriftí in the precision with which the ages are determined (Kerstan, 1995). This drift has to be assessed in order to exclude a series of readings which may have been based on different or, worse, inconsistent criteria.

A rapid analysis of the precision of the reader is possible using the average percent error (APE) given in Beamish and Fournier (1981). A reader produces the three readings of the same (sufficiently large) batch of otoliths in monthly or bi-monthly intervals. The lengths of the fishes must not be known. The APE is then calculated for the three series of readings, assuming that each of the three readings may be the accurate one (Kerstan, 1995). If, for instance, the last two readings provide substantially lower imprecisions (Kerstan, 1995), a drift occurred between the first and the second reading. In this example, the first series of readings is biased and all age determinations, which do not result in identical ages in all three readings, have to be eliminated from the first series. In this case, a fourth reading becomes necessary.

The continuous check of the reader's precision during the initial phase of his/her training is an essential tool to improve the precision and the knowledge of the reader.

It is recommended that each institute keep a <u>reference collection of otoliths</u> which all readers have to age in intervals in order to see whether their age determination criteria change with time. If readers have not been determining ages for longer periods of time they should restart with the reference collection in order to tune themselves.

10 RECOMMENDATIONS

1) The Workshop recommends that the Mackerel, Horse Mackerel, Sardine and Anchovy Assessment Working Group uses age groups up to and including age 11 with a 12+ age group for horse mackerel (biological data containing a 15+ group should be provided to the Working Group).

2) Horse mackerel otolith exchanges should be conducted regularly to check for any changes in agreement between readers of the different countries.

3) The Workshop recommends to conduct a comparison between two different otolith preparation techniques, the sliced transverse section technique versus the traditional broken/burnt transverse section technique. The best otolith readers of this Workshop should read the broken/burnt otoliths of set K as well as sliced transverse sections of the same set (which were the whole otoliths of set K used at this Workshop). Elizabeth Barnwall, Ireland will co-ordinate the otolith exchange and the comparison of otolith preparation methods.

4) The measurement of the annual growth zones within the otolith is important to reduce the possibility of inaccurately counting false rings in younger fish otoliths.

5) The Workshop recommends that each institute keep a reference collection of otoliths, which all readers have to age in intervals in order to see whether their age determination criteria change over time.

11 SUMMARY

The results from the 1996 horse mackerel otolith exchange showed that a horse mackerel otolith workshop was needed to deal with serious problems in age reading. The ages of fish from approximately age 8 onwards were underestimated. This bias increased to approximately one year of underestimation at age 13. Furthermore the interpretation of the edge of otoliths appeared to be a major difficulty, if these were taken from fish caught in the second half of the year (otoliths collected in the first half of the year have only translucent edges, while otoliths collected in the second half of the year have both translucent and opaque edges). To solve these problems a Horse Mackerel Otolith Workshop was held at CEFAS, Lowestoft, England from 15–19 January 1999, at which 15 otolith readers participated.

Three sets of otoliths were used, which contained only otoliths of the extremely strong 1982 year class collected during the period 1983 -1995. These otoliths had a very high probability that the originally estimated age was correct and were therefore treated as otoliths of 'known' or 'actual' age.

Two otolith sets were used for training. The first set contained otoliths with only translucent edges and the second otoliths with both translucent and opaque edges. The age reading comparisons of the first set showed that the precision was low for many readers and that the ages of the older fish were underestimated. The results from the second set showed that the underestimation of older ages was less. However, the precision was much lower compared to the first set, most likely due to difficulties in the interpretation of the otolith edge. Discussions on the results of both training otolith sets and the discussions on specific otoliths projected on a large screen resulted in an improvement of the ageing method of almost all readers. There was an evident improvement in precision and accuracy for almost all readers, but the underestimation in the ageings of the older age groups (bias) could not be decreased significantly during this workshop.

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Table 3.1 HORSE MACKEREL OTOLITH EXCHANGE 1996 SET A (revised)

Divisions VIa and VIIb, c, h, j, k

		Fish	Fish	Catch	-	NETH SR	SPAIN PA	SPAIN IR	PORT LS	NORW HG	IREL EB	GERM AC	S.AFR MK	-	ACTUAL	Age	
Year	Sample	no	length	month	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10	AGE	difference	Average
85	5	30	21.8	4	-	3	3	-	3	-	3	3	3	-	3	0	3.00
86	11	1	21.9	4	-	3	4	-	4	-	4	4	4	-	4	1	3.83
85	5	27	21.9	4	-	3	3	-	3	-	4	3	3	-	3	1	3.17
85	3	44	22.1	3	-	3	3	-	3	-	3	3	3	-	3	0	3.00
85	3	45	22.1	3	-	3	4	-	4	-	4	3	3	-	3	1	3.50
85	3	14	22.3	3	-	3	3	-	3	-	3	3	3	-	3	0	3.00
86	14	2	22.4	5	-	4	4	-	4	-	4	4	4	-	4	0	4.00
85	5	20	22.6	4	-	2	3	-	3	-	3	3	3	-	3	1	2.83
86	7	1	22.6	4	-	3	4	3	4	3	3	4	4	-	4	1	3.50
86	2	11	22.9	2	-	4	4	3	3	3	2	4	4	-	4	2	3.38
85	5	35	23.3	4	-	3	3	-	3	-	2	3	3	-	3	1	2.83
86	7	3	23.4	4	-	3	4	3	4	3	3	4	4	-	4	1	3.50
86	14	6	23.5	5	-	4	4	3	4	4	3	4	4	-	4	1	3.75
85	5	22	23.5	4	-	4	3	-	4	-	3	4	3	-	3	1	3.50
86	11	6	23.7	4	-	4	4	3	4	3	3	4	4	-	4	1	3.63
86	1	6	23.8	2	-	3	4	4	4	4	3	4	4	-	4	1	3.75
86	1	7	23.8	2	-	4	4	4	4	4	3	4	4	-	4	1	3.88
87	6	4	24.0	3	-	4	4	4	5	5	5	5	5	-	5	1	4.63
85	3	49	24.1	3	-	3	3	-	4	-	3	3	3	-	3	1	3.17
86	9	1	24.1	4	-	4	4	3	4	4	3	4	4	-	4	1	3.75
86	1	8	24.5	2	-	4	4	3	4	4	4	4	4	-	4	1	3.88
85	5	24	24.8	4	-	3	4	-	4	-	4	3	3	-	3	1	3.50
86	6	3	24.8	3	-	4	4	3	4	5	4	4	4	-	4	2	4.00
91	4	1	24.8	3	-	7	9	7	6	7	5	8	9	-	9	4	7.13
86	11	7	24.9	4	-	4	4	4	4	6	5	4	4	-	4	2	4.38
86	14	16	25.1	5	-	4	4	3	4	-	4	4	4	-	4	1	3.86
87	9	6	25.1	3	-	5	4	4	5	5	3	5	5	-	5	2	4.50
86	1	10	25.2	2	-	4	4	5	4	5	5	4	4	-	4	1	4.38
86	1	14	25.3	2	-	5	4	3	4	-	4	4	4	-	4	2	4.00
86	6	5	25.3	3	-	5	4	4	4	5	4	5	4	-	4	1	4.38
86	1	16	25.4	2	-	4	4	3	4	4	4	4	4	-	4	1	3.88
88	6	2	25.4	2	-	5	5	5	5	5	6	5	6	-	6	1	5.25
86	11	13	25.4	4	-	5	4	5	4	6	5	4	4	-	4	2	4.63
86	10	10	25.5	4	-	4	4	-	4	-	5	4	5	-	4	1	4.33
87	8	9	25.7	3	-	5	5	4	5	6	5	5	5	-	5	2	5.00
88	3	2	25.7	2	-	5	6	5	5	6	6	6	6	-	6	1	5.63
87	8	5	25.7	3	-	5	5	5	4	5	4	5	5	-	5	1	4.75
88	1	4	25.8	2	-	5	6	4	5	6	5	6	6	-	6	2	5.38
90	4	1	25.8	2	-	6	7	7	5	7	8	7	8	-	8	3	6.88
87	6	12	25.8	3	-	5	5	4	5	5	5	5	5	-	5	1	4.88
91	3	2	25.8	2	-	7	8	7	5	8	7	7	8	-	8	3	7.13
87	5	4	25.8	3	-	5	5	5	5	5	5	5	5	-	5	0	5.00
87	5	7	25.8	3	-	4	4	4	5	4	5	5	5	-	5	1	4.50
88	5	1	25.8	2	-	5	5	4	6	4	5	6	6	-	6	2	5.13
88	1	12	25.9	2	-	5	5	5	5	5	5	6	6	-	6	1	5.25
87	2	7	25.9	3	-	5	5	4	5	5	5	5	4	-	5	1	4.75
92	6	1	26.1	3	-	6	9	8	6	8	8	9	10	-	10	4	8.00
92	2	1	26.2	2	-	6	8	9	6	8	9	8	8	-	10	3	7.75
86	6	7	26.3	3	-	5	4	5	5	4	5	4	4	-	4	1	4.50
90	3	3	26.3	2	-	6	7	7	6	7	7	7	7	-	8	1	6.75
87	5	9	26.3	3	-	6	5	5	5	5	7	5	6	-	6	2	5.50
92	2	2	26.3	2	-	8	9	9	5	9	9	9	10	-	10	5	8.50
87	4	6	26.3	3	-	5	5	5	6	-	6	5	5	-	5	1	5.29
88	4	13	26.3	2	-	5	5	5	5	5	5	6	5	-	6	1	5.13
88	2	6	26.4	2	-	5	6	6	5	5	5	6	6	-	6	1	5.50
87	7	9	26.4	3	-	5	5	4	5	5	4	5	5	-	5	1	4.75
89	7	1	26.4	3	-	7	6	5	5	6	7	7	7	-	7	2	6.25
93	17	3	26.5	3	-	8	10	11	7	8	8	9	11	-	11	4	9.00
86	14	22	26.5	5	-	4	4	-	6	-	4	5	5	-	4	2	4.67
86	7	18	26.7	4	-	5	4	5	5	6	4	5	4	-	4	2	4.75
89	1	2	26.7	2	-	7	6	7	5	7	8	7	7	-	7	3	6.75
88	4	6	26.7	2	-	6	6	5	6	6	6	6	6	-	6	1	5.88
87	7	10	26.8	3	-	6	5	4	6	4	5	5	5	-	6	2	5.00
93	4	4	26.9	1	-	10	10	10	5	9	10	9	9	-	11	5	9.00
95	1	2	27.0	1	-	11	13	12	7	11	13	12	11	-	13	6	11.25
87	7	15	27.0	3	-	6	5	5	7	5	5	5	5	-	5	2	5.38
90	2	3	27.0	2	-	7	7	7	10	8	8	7	8	-	8	3	7.75
93	10	21	27.1	1	-	10	10	10	5	11	9	10	11	-	11	6	9.50
87	7	17	27.1	3	-	6	5	4	8	5	5	5	5	-	5	4	5.38
87	4	14	27.2	3	-	7	5	4	5	5	4	5	5	-	5	3	5.00
88	3	16	27.2	2	-	7	6	5	6	6	5	6	6	-	6	2	5.88
89	7	8	27.3	3	-	7	7	6	7	6	8	7	7	-	7	2	6.88
91	7	4	27.3	3	-	8	8	7	7	9	10	8	9	-	9	3	8.25
88	4	18	27.3	2	-	7	5	5	6	6	7	6	6	-	6	2	6.00
90	7	7	27.3	3	-	8	8	6	7	7	9	7	8	-	8	3	7.50
93	5	5	27.4	1	-	11	10	11	8	11	11	10	10	-	11	3	10.25
88	2	13	27.4	2	-	9	5	7	5	7	10	5	6	-	6	5	6.75
92	3	6	27.5	2	-	8	9	9	7	10	9	7	8	-	10	3	8.38
93	5	6	27.6	1	-	11	10	10	7	10	10	10	10	-	11	4	9.75
90	4	4	27.6	2	-	8	7	6	6	6	7	7	8	-	8	2	6.88
90	7	8	27.7	3	-	8	7	7	7	8	10	7	8	-	8	3	7.75
90	5	5	27.8	3	-	8	7	7	7	8	9	7	8	-	8	2	7.63
88	5	12	27.8	2	-	7	6	6	6	7	10	6	5	-	6	5	6.63
91	1	3	27.9	2	-	9	8	8	8	8	11	9	8	-	9	3	8.63
88	6	10	27.9	2	-	7	6	6	6	5	7	6	6	-	6	2	6.13
90	5	6	27.9	3	-	8	7	7	8	8	8	8	8	-	8	1	7.75
90	7	11	28.0	3	-	8	8	7	8	8	8	8	8	-	8	1	7.88
89	6	8	28.0	3	-	8	6	6	7	8	7	7	7	-	7	2	7.00
88	6	16	28.1	2	-	7	6	6	7	6	5	6	6	-	6	2	6.13
89	1	10	28.1	2	-	8	7	9	7	8	7	7	7	-	7	2	7.50
92	3	15	28.2	2	-	9	9	8	8	9	9	9	10	-	10	2	8.88
94	4	1	28.2	1	-	10	10	10	8	11	11	8	10	-	12	3	9.75
90	3	7	28.2	2	-	11	7	7	7	7	8	7	8	-	8	4	7.75
90	2	6	28.2	2	-	7	7	7	7	8	8	7	8	-	8	1	7.38
92	6	14	28.2	3	-	11	10	9	9	9	10	9	10	-	10	2	9.63
93	8	20	28.2	1	-	9	8	10	9	9	9	6	10	-	11	2	9.00
90	7	12	28.3	3	-	8	7	7	8	7	7	7	8	-	8	1	7.38
89	3	2	28.3	2	-	8	6	7	7	8	5	8	8	-	7	3	7.13
93	18	11	28.3	3	-	10	11	9	8	9	10	9	9	-	11	3	9.38
94	4	4	28.3	1	-	9	10	11	7	11	9	9	10	-	12	4	9.50

89	5	5	28.3	3	-	8	7	6	6	7	6	6	7	-	7	2	6.63
95	7	3	28.4	1	-	11	12	11	9	11	10	12	12	-	13	3	11.00
89	8	7	28.4	3	-	8	6	6	7	7	7	7	7	-	7	2	6.88
92	7	5	28.4	3	-	8	9	7	8	10	9	8	8	-	10	3	8.38
90	7	10	28.5	3	-	9	8	7	7	9	8	9	8	-	8	2	8.13
94	1	5	28.5	1	-	10	10	11	10	11	8	10	9	-	12	3	9.88
93	17	12	28.6	3	-	9	8	9	7	10	10	8	8	-	11	3	8.63
90	3	8	28.7	2	-	10	7	7	7	9	8	8	8	-	8	3	8.00
89	8	10	28.7	3	-	9	6	8	7	8	8	7	7	-	7	3	7.50
95	5	3	28.7	1	-	9	11	9	10	11	11	11	12	-	13	3	10.50
88	2	16	28.7	2	-	7	6	6	7	7	6	7	6	-	6	1	6.50
95	6	5	28.7	1	-	14	12	10	11	12	12	12	10	-	13	4	11.63
87	4	18	28.7	3	-	-	5	-	6	-	5	-	5	-	5	1	5.25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
95	7	8	28.8	1	-	12	10	13	10	12	12	12	12	-	13	3	11.63
93	19	8	28.9	3	-	12	10	11	10	11	10	10	11	-	11	2	10.63
90	5	17	29.0	3	-	10	7	8	8	9	9	8	8	-	8	3	8.38
89	6	16	29.1	3	-	9	7	9	7	9	9	8	7	-	7	2	8.13
94	2	13	29.2	1	-	10	10	12	11	12	10	11	10	-	12	2	10.75
92	5	18	29.3	2	-	11	9	9	9	10	8	10	10	-	10	3	9.50
94	1	10	29.3	1	-	13	11	11	11	12	11	12	11	-	12	2	11.50
90	7	15	29.3	3	-	9	8	7	8	10	8	8	8	-	8	3	8.25
91	6	6	29.3	3	-	11	8	9	8	9	7	9	9	-	9	4	8.75
91	2	14	29.3	2	-	10	8	8	9	10	8	9	9	-	9	2	8.88
89	6	14	29.4	3	-	9	7	9	8	8	8	9	7	-	7	2	8.13
95	7	11	29.5	1	-	13	12	12	7	13	11	12	13	-	13	6	11.63
95	6	7	29.5	5	-	11	12	12	12	12	11	11	11	-	13	1	11.50
91	2	13	29.5	2	-	11	8	9	9	10	10	9	8	-	9	3	9.25
90	2	9	29.5	2	-	9	8	8	8	11	9	9	8	-	8	3	8.75
95	9	13	29.6	1	-	13	12	11	11	13	11	12	-	-	13	2	11.86
88	3	22	29.6	2	-	8	6	7	7	7	6	8	6	-	6	3	7 00
94	2	12	29.7	1	-	11	11	11	11	11	11	11	9	-	12	2	10.75
89	1	13	29.7	2	-	10	7	7	7	7	8	8	7	-	7	3	7.63
92	8	18	29.7	3	-	13	9	11	9	8	9	10	10	-	10	5	9.88
92	3	20	29.7	2	-	11	9	9	9	10	9	10	10	-	10	2	9.63
90	5	18	29.7	3	-	11	7	9	8	8	7	8	8	-	8	4	8.25
92	6	16	29.7	3	-	11	10	10	9	12	9	11	9	-	10	3	10 13
91	1	10	29.7	2	-	10	8	9	8	11	8	9	9	-	9	3	9.00
89	6	15	29.8	3	-	11	7	8	7	9	7	8	7	-	7	4	8.00
95	8	1	29.8	1	-	12	12	10	12	12	11	11	12	-	13	2	11.50
89	3	8	30.0	2	-	13	7	8	7	9	10	9	7	-	7	6	8.75
90	3	20	30.0	2	-	10	7	7	8	11	7	9	8	-	8	4	8.38
90	5	19	30.1	3	-	11	8	7	8	9	7	9	8	-	8	4	8.38
95	4	13	30.1	1	-	12	13	10	10	12	11	11	-	-	13	3	11.29
93	2	11	30.1	1	-	12	11	11	10	11	10	11	9	-	11	3	10.63
92	1	2	30.2	2	-	11	10	9	9	10	10	11	9	-	10	2	9.88
91	1	14	30.4	2	-	10	8	8	8	9	8	9	7	-	9	3	8.38
90	5	20	30.4	3	-	9	8	8	9	8	8	9	8	-	8	1	8.38
90	4	12	30.5	2	-	9	8	8	8	8	8	9	8	-	8	1	8.25
90	5	21	30.5	3	-	11	7	7	9	9	7	9	7	-	8	4	8.25
89	2	3	30.5	2	-	8	7	6	7	8	7	8	7	-	7	2	7.25
90	4	11	30.7	2	-	9	7	7	8	8	7	8	8	-	8	2	7.75
89	2	2	30.7	2	-	9	7	7	7	7	7	8	7	-	7	2	7.38
90	4	13	30.7	2	-	13	7	7	9	-	7	9	8	-	8	6	8.57
89	7	20	30.8	3	-	9	7	8	7	-	8	8	8	-	7	2	7.86
92	7	10	30.9	3	-	11	10	9	9	11	9	10	10	-	10	2	9.88
93	7	9	31.0	1	-	11	10	10	10	11	10	10	9	-	11	2	10.13
89	6	22	31.0	3	-	10	7	6	7	10	11	8	7	-	7	5	8.25
95	6	16	31.0	1	-	11	13	11	12	13	13	12	9	-	13	4	11.75
92	6	19	31.2	3	-	9	9	10	9	9	11	11	9	-	10	2	9.63
92	7	16	31.3	3	-	12	9	8	7	10	12	12	8	-	10	5	9.75
89	3	10	31.3	2	-	11	6	7	7	7	7	8	7	-	7	5	7.50
92	7	17	31.3	3	-	14	10	8	10	10	11	11	8	-	10	6	10.25
91	6	11	31.3	3	-	13	8	8	8	8	10	9	9	-	9	5	9.13
91	7	15	31.4	3	-	11	7	8	8	8	9	9	9	-	9	4	8.63
90	3	22	31.4	2	-	11	8	9	9	8	9	9	8	-	8	3	8.88
94	5	4	31.5	1	-	11	10	11	11	12	11	12	9	-	12	3	10.88
93	1	13	31.7	1	-	12	10	9	8	12	11	11	10	-	11	4	10.38
94	5	5	31.8	1	-	14	12	12	12	12	12	12	11	-	12	3	12.13
94	3	3	31.9	1	-	14	11	11	11	12	12	13	8	-	12	6	11 50
92	7	19	32.0	3	-	11	10	9	9	9	7	10	10	-	10	4	9 38
93	2	16	32.1	1	-	11	11	12	11	11	10	12	11	-	11	2	11.13
91	3	21	32.2	2	-	12	9	8	10	9	8	10	9	-	9	4	9.38
94	2	21	32.2	1	-	12	11	10	12	11	11	10	10	-	12	2	10 88
91	6	15	32.2	3	-	13	9	9	12	10	9	10	9	-	9	4	10.13
91	1	19	32.3	2	-	9	9	9	9	9	7	9	9	-	9	2	8.75
90	7	22	32.3	3	-	11	8	7	9	8	8	9	8	-	8	4	8 50
92	4	11	32.4	2	-	12	9	10	10	9	8	11	10	-	10	4	9.88
93	5	19	32.4	1	-	12	10	11	9	11	10	11	10	-	11	3	10.50
95	6	20	32.5	1	-	12	11	13	10	11	12	13	12	-	13	3	11.75
92	4	13	32.8	2	-	13	10	10	10	12	12	13	10	-	10	3	11.25
93	5	21	33.3	1	-	13	10	9	10	11	11	12	10	-	11	4	10.75
93	5	20	33.3	1	-	14	11	12	12	11	14	13	11	-	11	3	12.25
91	4	21	33.5	3	-	10	8	8	9	8	15	11	9	-	9	7	9.75
94	3	11	33.5	1	-	12	9	10	10	11	11	11	12	-	12	3	10.75
92	2	24	33.7	2	-	14	9	9	10	10	11	11	10	-	10	5	10.50
94	2	24	33.7	1	-	15	11	11	11	11	14	12	12	-	12	4	12.13
95	4	19	33.7	1	-	13	13	14	13	13	12	13	13	-	13	2	13.00
95	4	21	33.8	1	-	14	12	12	12	11	13	13	13	-	13	3	12.50
94	5	23	34.1	1	-	16	10	11	11	12	11	12	12	-	12	6	11.88
94	4	17	34.2	1	-	14	10	10	12	11	12	10	11	-	12	4	11.25
95	8	14	34.4	1	-	16	14	12	13	13	15	13	-	-	13	4	13.71
93	3	22	34.4	1	-	13	10	10	11	11	11	12	11	-	11	3	11.13
93	6	15	34.5	1	-	13	10	9	12	11	11	12	12	-	11	4	11.25
95	8	17	34.6	1	-	15	13	11	12	13	15	12	9	-	13	6	12.50
93	1	22	35.0	1	-	13	9	9	10	9	9	13	11	-	11	4	10.38
94	4	19	35.2	1	-	15	11	11	13	11	12	11	12	-	12	4	12.00
93	1	24	35.4	1	-	14	10	12	12	9	11	11	10	-	11	5	11.13
95	4	23	35.8	1	-	17	12	12	11	12	11	13	11	-	13	6	12.38
94	4	23	36.0	1	-	16	11	14	13	12	12	15	12	-	12	5	13.13
				Total read	0	198	199	184	199	179	199	198	196	0			
				Total NOT read	199	1	0	15	0	20	0	1	3	199			
				Empty rows	1	1	1	1	1	1	1	1	1	1			

HORSE MACKEREL OTOLITH EXCHANGE 1996 SET A (revised)

Table 3.2 **The mean age recorded, 2stdev, the number of age readings and the agreement with actual age are presented by actual age for each reader and for all readers combined. The total number of age readings and the weighted means of CV and agreement is given for age groups 0-15. Precision is indicated by CV and accuracy by agreement.**

Reader 1
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Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
CV (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with actual age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

Reader 2
NETH SR

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	3.00	4.04	5.27	6.31	8.89	9.07	10.07	10.45	11.40	12.63	12.71	-	-	
2stdev	-	-	-	0.94	1.28	1.60	2.80	3.12	3.42	3.74	4.75	3.40	4.61	4.05	-	-	
CV (%)	-	-	-	16%	16%	15%	22%	18%	19%	19%	23%	15%	18%	16%	-	-	18%
Number of age readings	-	-	-	10	23	15	16	19	27	15	20	20	16	17	-	-	198
Agreement with actual age	-	-	-	80%	61%	53%	6%	16%	26%	13%	0%	20%	13%	18%	-	-	26%

Reader 3
SPAIN PA

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	3.20	4.00	4.81	5.63	6.63	7.37	8.20	9.30	9.95	10.50	12.18	-	-	
2stdev	-	-	-	0.84	0.00	0.81	1.00	0.89	0.98	1.12	1.14	1.65	1.46	1.90	-	-	
CV (%)	-	-	-	13%	0%	8%	9%	7%	7%	7%	6%	8%	7%	8%	-	-	7%
Number of age readings	-	-	-	10	23	16	16	19	27	15	20	20	16	17	-	-	199
Agreement with actual age	-	-	-	80%	100%	81%	63%	63%	37%	27%	35%	20%	6%	29%	-	-	49%

Reader 4
SPAIN IR

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	3.63	4.33	5.44	7.11	7.22	8.13	9.00	10.25	11.06	11.47	-	-	
2stdev	-	-	-	-	1.66	0.98	1.78	2.39	1.40	1.49	1.84	2.14	2.00	2.56	-	-	
CV (%)	-	-	-	-	23%	11%	16%	17%	10%	9%	10%	10%	9%	11%	-	-	13%
Number of age readings	-	-	-	-	19	15	16	19	27	15	20	20	16	17	-	-	184
Agreement with actual age	-	-	-	-	21%	33%	31%	26%	15%	33%	20%	25%	13%	12%	-	-	22%

Reader 5
PORT LS

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	3.40	4.13	5.44	5.75	6.79	7.74	8.20	8.40	9.05	10.88	10.71	-	-	
2stdev	-	-	-	1.03	1.10	1.93	1.55	1.43	2.19	3.48	2.93	4.28	3.17	3.59	-	-	
CV (%)	-	-	-	15%	13%	18%	13%	11%	14%	21%	17%	24%	15%	17%	-	-	16%
Number of age readings	-	-	-	10	23	16	16	19	27	15	20	20	16	17	-	-	199
Agreement with actual age	-	-	-	60%	83%	63%	38%	79%	41%	27%	20%	10%	19%	12%	-	-	41%

Reader 6
NORW HG

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	4.29	4.93	5.81	7.72	8.23	8.87	9.65	10.30	11.44	12.06	-	-	
2stdev	-	-	-	-	2.09	0.95	1.82	2.15	2.35	2.12	2.27	2.16	1.02	1.65	-	-	
CV (%)	-	-	-	-	24%	10%	16%	14%	14%	12%	12%	10%	4%	7%	-	-	12%
Number of age readings	-	-	-	-	17	14	16	18	26	15	20	20	16	17	-	-	179
Agreement with actual age	-	-	-	-	41%	79%	38%	33%	46%	33%	40%	55%	44%	35%	-	-	44%

Reader 7
IREL EB

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	3.20	3.83	4.88	6.19	7.63	7.93	8.80	9.45	10.25	11.13	12.00	-	-	
2stdev	-	-	-	1.26	1.67	1.77	3.28	2.68	1.66	4.61	2.71	2.42	2.72	2.83	-	-	
CV (%)	-	-	-	20%	22%	18%	27%	18%	10%	26%	14%	12%	12%	12%	-	-	17%
Number of age readings	-	-	-	10	23	16	16	19	27	15	20	20	16	17	-	-	199
Agreement with actual age	-	-	-	60%	43%	63%	31%	42%	44%	13%	10%	30%	31%	18%	-	-	35%

Reader 8
GERM AC

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	3.10	4.13	5.00	6.06	7.63	8.00	9.00	10.00	10.55	11.19	12.06	-	-	
2stdev	-	-	-	0.63	0.69	0.00	1.36	1.52	1.75	1.85	2.90	3.01	3.28	1.50	-	-	
CV (%)	-	-	-	10%	8%	0%	11%	10%	11%	10%	15%	14%	15%	6%	-	-	10%
Number of age readings	-	-	-	10	23	15	16	19	27	15	20	20	16	17	-	-	198
Agreement with actual age	-	-	-	90%	87%	100%	75%	37%	26%	60%	25%	20%	31%	29%	-	-	49%

Reader 9
S.AFR MK

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	3.00	4.09	5.00	5.88	7.11	7.93	8.67	9.35	10.15	10.50	11.43	-	-	
2stdev	-	-	-	0.00	0.58	0.73	0.68	0.63	0.53	1.23	1.75	1.98	2.63	2.68	-	-	
CV (%)	-	-	-	0%	7%	7%	6%	4%	3%	7%	9%	10%	13%	12%	-	-	7%
Number of age readings	-	-	-	10	23	16	16	19	27	15	20	20	16	14	-	-	196
Agreement with actual age	-	-	-	100%	91%	88%	88%	89%	93%	73%	60%	35%	31%	21%	-	-	71%

Reader 10
-

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
CV (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####
Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Agreement with actual age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

ALL READERS

Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Mean age recorded	-	-	-	3.15	4.02	4.96	5.88	7.44	7.93	8.74	9.45	10.24	11.16	11.83	-	-	
2stdev	-	-	-	0.89	1.28	1.36	1.99	2.40	2.21	2.92	2.91	2.95	3.02	2.89	-	-	
CV (%)	-	-	-	14%	16%	14%	17%	16%	14%	17%	15%	14%	14%	12%	-	-	15%
Number of age readings	-	-	-	60	174	123	128	151	215	120	160	160	128	133	-	-	1552
Agreement with actual age	-	-	-	78%	68%	70%	46%	48%	41%	35%	26%	27%	23%	22%	-	-	42%

Table 3.3 HORSE MACKEREL OTOLITH EXCHANGE 1996 SET A (revised)

Divisions VIa and VIIb, c, h, j, k

		Fish	Fish	Catch	-	NETH SR	SPAIN PA	SPAIN IR	PORT LS	NORW HG	IREL EB	GERM AC	S.AFR MK	-	MODAL	Age	
Year	Sample	no	length	month	Reader 1	Reader 2	Reader 3	Reader 4	Reader 5	Reader 6	Reader 7	Reader 8	Reader 9	Reader 10	AGE	difference	Average
85	5	30	21.8	4	-	3	3	-	3	-	3	3	3	-	3	0	3.00
86	11	1	21.9	4	-	3	4	-	4	-	4	4	4	-	4	1	3.83
85	5	27	21.9	4	-	3	3	-	3	-	4	3	3	-	3	1	3.17
85	3	44	22.1	3	-	3	3	-	3	-	3	3	3	-	3	0	3.00
85	3	45	22.1	3	-	3	4	-	4	-	4	3	3	-	3	1	3.50
85	3	14	22.3	3	-	3	3	-	3	-	3	3	3	-	3	0	3.00
86	14	2	22.4	5	-	4	4	-	4	-	4	4	4	-	4	0	4.00
85	5	20	22.6	4	-	2	3	-	3	-	3	3	3	-	3	1	2.83
86	7	1	22.6	4	-	3	4	3	4	3	3	4	4	-	3	1	3.50
86	2	11	22.9	2	-	4	4	3	3	3	2	4	4	-	4	2	3.38
85	5	35	23.3	4	-	3	3	-	3	-	2	3	3	-	3	1	2.83
88	7	3	23.4	4	-	3	4	3	4	3	3	4	4	-	3	1	3.50
86	14	6	23.5	5	-	4	4	3	4	4	3	4	4	-	4	1	3.75
85	5	22	23.5	4	-	4	3	-	4	-	3	4	3	-	4	1	3.50
86	11	6	23.7	4	-	4	4	3	4	3	3	4	4	-	4	1	3.63
86	1	6	23.8	2	-	3	4	4	4	4	3	4	4	-	4	1	3.75
88	1	7	23.8	2	-	4	4	4	4	4	3	4	4	-	4	1	3.88
87	8	4	24.0	3	-	4	4	4	5	5	5	5	5	-	5	1	4.63
85	3	49	24.1	3	-	3	3	-	4	-	3	3	3	-	3	1	3.17
86	9	1	24.1	4	-	4	4	3	4	4	3	4	4	-	4	1	3.75
86	1	8	24.5	2	-	4	4	3	4	4	4	4	4	-	4	1	3.88
85	5	24	24.8	4	-	3	4	-	4	-	4	3	3	-	3	1	3.50
86	6	3	24.8	3	-	4	4	3	4	5	4	4	4	-	4	2	4.00
91	4	1	24.8	3	-	7	9	7	5	7	5	8	9	-	7	4	7.13
86	11	7	24.9	4	-	4	4	4	4	6	5	4	4	-	4	2	4.38
86	14	16	25.1	5	-	4	4	3	4	-	4	4	4	-	4	1	3.86
87	9	6	25.1	3	-	5	4	4	5	5	3	5	5	-	5	2	4.50
86	1	10	25.2	2	-	4	4	5	4	5	5	4	4	-	4	1	4.38
86	1	14	25.3	2	-	5	4	3	4	-	4	4	4	-	4	2	4.00
86	6	5	25.3	3	-	5	4	4	4	5	4	5	4	-	4	1	4 38
86	1	16	25.4	2	-	4	4	3	4	4	4	4	4	-	4	1	3.88
88	6	2	25.4	2	-	5	5	5	5	5	6	5	6	-	5	1	5.25
86	11	13	25.4	4	-	5	4	5	4	6	5	4	4	-	4	2	4.63
86	10	10	25.5	4	-	4	4	-	4	-	5	4	5	-	4	1	4.33
87	8	9	25.7	3	-	5	5	4	5	6	5	5	5	-	5	2	5.00
88	3	2	25.7	2	-	5	6	5	5	6	6	6	6	-	6	1	5.63
87	8	5	25.7	3	-	5	5	5	4	5	4	5	5	-	5	1	4.75
88	1	4	25.8	2	-	5	6	4	5	6	5	6	6	-	6	2	5.38
90	4	1	25.8	2	-	6	7	7	5	7	8	7	8	-	7	3	6.88
87	6	12	25.8	3	-	5	5	4	5	5	5	5	5	-	5	1	4.88
91	3	2	25.8	2	-	7	8	7	5	8	7	7	8	-	7	3	7.13
87	5	4	25.8	3	-	5	5	5	5	5	5	5	5	-	5	0	5.00
87	5	7	25.8	3	-	4	4	4	5	4	5	5	5	-	4	1	4.50
88	5	1	25.8	2	-	5	5	4	6	4	5	6	6	-	5	2	5.13
88	1	12	25.9	2	-	5	5	5	5	5	5	6	6	-	5	1	5.25
87	2	7	25.9	3	-	5	5	4	5	5	5	5	4	-	5	1	4.75
92	6	1	26.1	3	-	6	9	8	6	8	8	9	10	-	8	4	8.00
92	2	1	26.2	2	-	6	8	9	6	8	9	8	8	-	8	3	7.75
86	6	7	26.3	3	-	5	4	5	5	4	5	4	4	-	5	1	4.50
90	3	3	26.3	2	-	6	7	7	6	7	7	7	7	-	7	1	6.75
87	5	9	26.3	3	-	6	5	5	5	5	7	5	6	-	5	2	5.50
92	2	2	26.3	2	-	8	9	9	5	9	9	9	10	-	9	5	8.50
87	4	6	26.3	3	-	5	5	5	6	-	6	5	5	-	5	1	5.29
88	4	13	26.3	2	-	5	5	5	5	5	5	6	5	-	5	1	5.13
88	2	6	26.4	2	-	5	6	6	5	5	5	6	6	-	5	1	5.50
87	7	9	26.4	3	-	5	5	4	5	5	4	5	5	-	5	1	4.75
89	7	1	26.4	3	-	7	6	5	5	6	7	7	7	-	7	2	6.25
93	17	3	26.5	3	-	8	10	11	7	8	8	9	11	-	8	4	9.00
86	14	22	26.5	5	-	4	4	-	6	-	4	5	5	-	4	2	4.67
86	7	18	26.7	4	-	5	4	5	5	6	4	5	4	-	5	2	4.75
89	1	2	26.7	2	-	7	6	7	5	7	8	7	7	-	7	3	6.75
88	4	6	26.7	2	-	6	6	5	6	6	6	6	6	-	6	1	5.88
87	7	10	26.8	3	-	6	5	4	6	4	5	5	5	-	5	2	5.00
93	4	4	26.9	1	-	10	10	10	5	9	10	9	9	-	10	5	9.00
95	1	2	27.0	1	-	11	13	12	7	11	13	12	11	-	11	6	11.25
87	7	15	27.0	3	-	6	5	5	7	5	5	5	5	-	5	2	5.38
90	2	3	27.0	2	-	7	7	7	10	8	8	7	8	-	7	3	7.75
93	10	21	27.1	1	-	10	10	10	5	11	9	10	11	-	10	6	9.50
87	7	17	27.1	3	-	6	5	4	8	5	5	5	5	-	5	4	5 38
87	4	14	27.2	3	-	7	5	4	5	5	4	5	5	-	5	3	5.00
88	3	16	27.2	2	-	7	6	5	6	6	5	6	6	-	6	2	5.88
89	7	8	27.3	3	-	7	7	6	7	6	8	7	7	-	7	2	6.88
91	7	4	27.3	3	-	8	8	7	7	9	10	8	9	-	8	3	8.25
88	4	18	27.3	2	-	7	5	5	6	6	7	6	6	-	6	2	6.00
90	7	7	27.3	3	-	8	8	6	7	7	9	7	8	-	8	3	7 50
93	5	5	27.4	1	-	11	10	11	8	11	11	10	10	-	11	3	10.25
88	2	13	27.4	2	-	9	5	7	5	7	10	5	6	-	5	5	6.75
92	3	6	27.5	2	-	8	9	9	7	10	9	7	8	-	9	3	8.38
93	5	6	27.6	1	-	11	10	10	7	10	10	10	10	-	10	4	9.75
90	4	4	27.6	2	-	8	7	6	6	6	7	7	8	-	7	2	6.88
90	7	8	27.7	3	-	8	7	7	7	8	10	7	8	-	7	3	7.75
90	5	5	27.8	3	-	8	7	7	7	8	9	7	8	-	7	2	7.63
88	5	12	27.8	2	-	7	6	6	6	7	10	6	5	-	6	5	6.63
91	1	3	27.9	2	-	9	8	8	8	8	11	9	8	-	8	3	8.63
88	6	10	27.9	2	-	7	6	6	6	5	7	6	6	-	6	2	6.13
90	5	6	27.9	3	-	8	7	7	8	8	8	8	8	-	8	1	7.75
90	7	11	28.0	3	-	8	8	7	8	8	8	8	8	-	8	1	7.88
89	6	8	28.0	3	-	8	6	6	7	8	7	7	7	-	7	2	7.00
88	6	18	28.1	2	-	7	6	6	7	6	5	6	6	-	6	2	6.13
89	1	10	28.1	2	-	8	7	9	7	8	7	7	7	-	7	2	7 50
92	3	15	28.2	2	-	9	9	8	8	9	9	9	10	-	9	2	8.88
94	4	1	28.2	1	-	10	10	10	8	11	11	8	10	-	10	3	9.75
90	3	7	28.2	2	-	11	7	7	7	7	8	7	8	-	7	4	7.75
90	2	6	28.2	2	-	7	7	7	7	8	8	7	8	-	7	1	7.38
92	6	14	28.2	3	-	11	10	9	9	9	10	9	10	-	9	2	9.63
93	8	20	28.2	1	-	9	8	10	9	9	9	8	10	-	9	2	9.00
90	7	12	28.3	3	-	8	7	7	8	7	7	7	8	-	7	1	7.38
89	3	2	28.3	2	-	8	6	7	7	8	5	8	8	-	8	3	7.13
93	18	11	28.3	3	-	10	11	9	8	9	10	9	9	-	9	3	9.38
94	4	4	28.3	1	-	9	10	11	7	11	9	9	10	-	9	4	9.50

89	5	5	28.3	3	-	8	7	6	6	7	6	6	7	-	6	2	6.63
95	7	3	28.4	1	-	11	12	11	9	11	10	12	12	-	11	3	11.00
89	8	7	28.4	3	-	8	6	8	7	7	7	7	7	-	7	2	6.88
92	7	5	28.4	3	-	8	9	7	8	10	9	8	8	-	8	3	8.38
90	7	10	28.5	3	-	9	8	7	7	9	8	9	8	-	9	2	8.13
94	1	5	28.5	1	-	10	10	11	10	11	8	10	9	-	10	3	9.88
93	17	12	28.6	3	-	9	8	9	7	10	10	8	8	-	8	3	8.63
90	3	8	28.7	2	-	10	7	7	7	9	8	8	8	-	7	3	8.00
89	8	10	28.7	3	-	9	6	8	7	8	8	7	7	-	8	3	7.50
95	5	3	28.7	1	-	9	11	9	10	11	11	11	12	-	11	3	10.50
88	2	16	28.7	2	-	7	6	6	7	7	6	7	6	-	7	1	6.50
95	6	5	28.7	1	-	14	12	10	11	12	12	12	10	-	12	4	11.63
87	4	18	28.7	3	-	-	5	-	6	-	5	-	5	-	5	1	5.25
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
95	7	6	28.8	1	-	12	10	13	10	12	12	12	12	-	12	3	11.63
93	19	8	28.9	3	-	12	10	11	10	11	10	10	11	-	10	2	10.63
90	5	17	29.0	3	-	10	7	8	8	9	9	8	8	-	8	3	8.38
89	6	16	29.1	3	-	9	7	9	7	9	9	8	7	-	9	2	8.13
94	2	13	29.2	1	-	10	10	12	11	12	10	11	10	-	10	2	10.75
92	5	18	29.3	2	-	11	9	9	9	10	8	10	10	-	9	3	9.50
94	1	10	29.3	1	-	13	11	11	11	12	11	12	11	-	11	2	11.50
90	7	15	29.3	3	-	9	8	7	8	10	8	8	8	-	8	3	8.25
91	6	6	29.3	3	-	11	8	9	8	9	7	9	9	-	9	4	8.75
91	2	14	29.3	2	-	10	8	8	9	10	8	9	9	-	8	2	8.88
89	6	14	29.4	3	-	9	7	9	8	8	8	9	7	-	9	2	8.13
95	7	11	29.5	1	-	13	12	12	7	13	11	12	13	-	13	6	11.63
95	6	7	29.5	5	-	11	12	12	12	12	11	11	11	-	11	1	11.50
91	2	13	29.5	2	-	11	8	9	9	10	10	9	8	-	9	3	9.25
90	2	9	29.5	2	-	9	8	8	8	11	9	9	8	-	8	3	8.75
95	9	13	29.6	1	-	13	12	11	11	13	11	12	-	-	11	2	11.86
88	3	22	29.6	2	-	9	6	7	7	7	6	8	8	-	6	3	7.00
94	2	12	29.7	1	-	11	11	11	11	11	11	11	9	-	11	2	10.75
89	1	13	29.7	2	-	10	7	7	7	7	8	8	7	-	7	3	7.63
92	6	18	29.7	3	-	13	9	11	9	8	9	10	10	-	9	5	9.88
92	3	20	29.7	2	-	11	9	9	9	10	9	10	10	-	9	2	9.63
90	5	18	29.7	3	-	11	7	9	8	8	7	8	8	-	8	4	8.25
92	6	16	29.7	3	-	11	10	10	9	12	9	11	9	-	9	3	10.13
91	1	10	29.7	2	-	10	8	9	8	11	8	9	9	-	8	3	9.00
89	6	15	29.8	3	-	11	7	8	7	9	7	8	7	-	7	4	8.00
95	8	1	29.8	1	-	12	12	10	12	12	11	11	12	-	12	2	11.50
89	3	8	30.0	2	-	13	7	8	7	9	10	9	7	-	7	6	8.75
90	3	20	30.0	2	-	10	7	7	8	11	7	9	8	-	7	4	8.38
90	5	19	30.1	3	-	11	8	7	8	9	7	9	8	-	8	4	8.38
95	4	13	30.1	1	-	12	13	10	10	12	11	11	-	-	12	3	11.29
93	2	11	30.1	1	-	12	11	11	10	11	10	11	9	-	11	3	10.63
92	1	2	30.2	2	-	11	10	9	9	10	10	11	9	-	10	2	9.88
91	1	14	30.4	2	-	10	8	8	8	9	8	9	7	-	8	3	8.38
90	5	20	30.4	3	-	9	8	8	9	8	8	9	8	-	8	1	8.38
90	4	12	30.5	2	-	9	8	8	8	8	8	9	8	-	8	1	8.25
90	5	21	30.5	3	-	11	7	7	9	9	7	9	7	-	7	4	8.25
89	2	3	30.5	2	-	8	7	6	7	8	7	8	7	-	7	2	7.25
90	4	11	30.7	2	-	9	7	7	8	8	7	8	8	-	8	2	7.75
89	2	2	30.7	2	-	9	7	7	7	7	7	8	7	-	7	2	7.38
90	4	13	30.7	2	-	13	7	7	9	-	7	9	8	-	7	6	8.57
89	7	20	30.8	3	-	9	7	8	7	-	8	8	8	-	8	2	7.86
92	7	10	30.9	3	-	11	10	9	9	11	9	10	10	-	10	2	9.88
93	7	9	31.0	1	-	11	10	10	10	11	10	10	9	-	10	2	10.13
89	6	22	31.0	3	-	10	7	6	7	10	11	8	7	-	7	5	8.25
95	6	16	31.0	1	-	11	13	11	12	13	13	12	9	-	13	4	11.75
92	6	19	31.2	3	-	9	9	10	9	9	11	11	9	-	9	2	9.63
92	7	16	31.3	3	-	12	9	8	7	10	12	12	8	-	12	5	9.75
89	3	10	31.3	2	-	11	6	7	7	7	7	8	7	-	7	5	7.50
92	7	17	31.3	3	-	14	10	8	10	10	11	11	8	-	10	6	10.25
91	6	11	31.3	3	-	13	8	8	8	8	10	9	9	-	8	5	9.13
91	7	15	31.4	3	-	11	7	8	8	8	9	9	9	-	8	4	8.63
90	3	22	31.4	2	-	11	8	9	9	8	9	9	8	-	9	3	8.88
94	5	4	31.5	1	-	11	10	11	11	12	11	12	9	-	11	3	10.88
93	1	13	31.7	1	-	12	10	9	8	12	11	11	10	-	12	4	10.38
94	5	5	31.8	1	-	14	12	12	12	12	12	12	11	-	12	3	12.13
94	3	3	31.9	1	-	14	11	11	11	12	12	13	8	-	11	6	11.50
92	7	19	32.0	3	-	11	10	9	9	9	7	10	10	-	10	4	9.38
93	2	16	32.1	1	-	11	11	12	11	11	10	12	11	-	11	2	11.13
91	3	21	32.2	2	-	12	9	8	10	9	8	10	9	-	9	4	9.38
94	2	21	32.2	1	-	12	11	10	12	11	11	10	10	-	11	2	10.88
91	6	15	32.2	3	-	13	9	9	12	10	9	10	9	-	9	4	10.13
91	1	19	32.3	2	-	9	9	9	9	9	7	9	9	-	9	2	8.75
90	7	22	32.3	3	-	11	8	7	9	8	8	9	8	-	8	4	8.50
92	4	11	32.4	2	-	12	9	10	10	9	8	11	10	-	10	4	9.88
93	5	19	32.4	1	-	12	10	11	9	11	10	11	10	-	10	3	10.50
95	6	20	32.5	1	-	12	11	13	10	11	12	13	12	-	12	3	11.75
92	4	13	32.8	2	-	13	10	10	10	12	12	13	10	-	10	3	11.25
93	5	21	33.3	1	-	13	10	9	10	11	11	12	10	-	10	4	10.75
93	5	20	33.3	1	-	14	11	12	12	11	14	13	11	-	11	3	12.25
91	4	21	33.5	3	-	10	8	8	9	8	15	11	9	-	8	7	9.75
94	3	11	33.5	1	-	12	9	10	10	11	11	11	12	-	11	3	10.75
92	2	24	33.7	2	-	14	9	9	10	10	11	11	10	-	10	5	10.50
94	2	24	33.7	1	-	15	11	11	11	11	14	12	12	-	11	4	12.13
95	4	19	33.7	1	-	13	13	14	13	13	12	13	13	-	13	2	13.00
95	4	21	33.8	1	-	14	12	12	12	11	13	13	13	-	12	3	12.50
94	5	23	34.1	1	-	16	10	11	11	12	11	12	12	-	11	6	11.88
94	4	17	34.2	1	-	14	10	10	12	11	12	10	11	-	10	4	11.25
95	8	14	34.4	1	-	16	14	12	13	13	15	13	-	-	13	4	13.71
93	3	22	34.4	1	-	13	10	10	11	11	11	12	11	-	11	3	11.13
93	6	15	34.5	1	-	13	10	9	12	11	11	12	12	-	12	4	11.25
95	8	17	34.6	1	-	15	13	11	12	13	15	12	9	-	15	6	12.50
93	1	22	35.0	1	-	13	9	9	10	9	9	13	11	-	9	4	10.38
94	4	19	35.2	1	-	15	11	11	13	11	12	11	12	-	11	4	12.00
93	1	24	35.4	1	-	14	10	12	12	9	11	11	10	-	10	5	11.13
95	4	23	35.8	1	-	17	12	12	11	12	11	13	11	-	12	6	12.38
94	4	23	36.0	1	-	16	11	14	13	12	12	15	12	-	12	5	13.13
				Total read	0	198	199	184	199	179	199	198	196	0			
				Total NOT read	199	1	0	15	0	20	0	1	3	199			
				Empty rows	1	1	1	1	1	1	1	1	1	1			

HORSE MACKEREL OTOLITH EXCHANGE 1996 SET A (revised)

Table 3.4 **The mean age recorded, 2stdev, the number of age readings and the agreement with modal age are presented by modal age for each reader and for all readers combined. The total number of age readings and the weighted means of CV and agreement is given for age groups 0-15. Precision is indicated by CV and accuracy by agreement.**

Reader 1	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
-	Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	CV (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####
	Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

Reader 2	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
NETH SR	Mean age recorded	-	-	-	2.91	4.05	5.41	6.80	8.66	9.14	10.27	11.74	12.37	13.33	13.25	-	15.00	
	2stdev	-	-	-	0.60	1.00	2.02	2.46	3.90	3.02	3.16	3.04	3.60	3.45	4.12	-	#####	
	CV (%)	-	-	-	10%	12%	19%	18%	23%	16%	15%	13%	15%	13%	16%	-	#####	16%
	Number of age readings	-	-	-	11	21	22	10	29	28	22	19	19	12	4	-	1	198
	Agreement with modal age	-	-	-	91%	76%	68%	10%	28%	25%	36%	26%	37%	50%	50%	-	100%	43%

Reader 3	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
SPAIN PA	Mean age recorded	-	-	-	3.36	3.95	4.87	6.00	6.90	7.79	8.82	9.89	10.95	11.17	13.00	-	13.00	
	2stdev	-	-	-	1.01	0.44	0.92	0.94	1.24	1.67	1.92	0.63	1.82	2.39	1.63	-	#####	
	CV (%)	-	-	-	15%	6%	9%	8%	9%	11%	11%	3%	8%	11%	6%	-	#####	9%
	Number of age readings	-	-	-	11	21	23	10	29	28	22	19	19	12	4	-	1	199
	Agreement with modal age	-	-	-	64%	95%	78%	80%	72%	61%	50%	89%	53%	42%	50%	-	0%	68%

Reader 4	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
SPAIN IR	Mean age recorded	-	-	-	3.00	3.56	4.68	5.50	6.83	7.86	9.14	10.00	10.95	11.00	12.25	-	11.00	
	2stdev	-	-	-	0.00	1.45	1.56	1.70	1.52	1.94	1.78	2.11	1.56	3.81	2.52	-	#####	
	CV (%)	-	-	-	0%	20%	17%	15%	11%	12%	10%	11%	7%	17%	10%	-	#####	13%
	Number of age readings	-	-	-	2	16	22	10	29	28	22	19	19	12	4	-	1	184
	Agreement with modal age	-	-	-	100%	31%	45%	40%	62%	46%	64%	42%	58%	25%	0%	-	0%	48%

Reader 5	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
PORT LS	Mean age recorded	-	-	-	3.45	4.10	5.35	6.00	6.90	7.75	8.50	9.26	10.63	10.67	11.25	-	12.00	
	2stdev	-	-	-	1.04	1.08	1.66	1.33	2.41	1.60	2.81	3.82	2.84	3.55	5.74	-	#####	
	CV (%)	-	-	-	15%	13%	16%	11%	17%	10%	17%	21%	13%	17%	26%	-	#####	15%
	Number of age readings	-	-	-	11	21	23	10	29	28	22	19	19	12	4	-	1	199
	Agreement with modal age	-	-	-	55%	86%	70%	60%	59%	54%	45%	42%	47%	33%	50%	-	0%	56%

Reader 6	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
NORW HG	Mean age recorded	-	-	-	3.00	4.36	5.05	6.20	7.71	8.63	9.32	10.47	11.37	11.58	13.00	-	13.00	
	2stdev	-	-	-	0.00	1.86	1.34	1.28	2.36	2.09	1.89	1.93	1.19	1.34	0.00	-	#####	
	CV (%)	-	-	-	0%	21%	13%	10%	15%	12%	10%	9%	5%	6%	0%	-	#####	11%
	Number of age readings	-	-	-	2	14	21	10	28	27	22	19	19	12	4	-	1	179
	Agreement with modal age	-	-	-	100%	50%	71%	60%	39%	59%	55%	21%	68%	67%	100%	-	0%	55%

Reader 7	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
IREL EB	Mean age recorded	-	-	-	3.18	3.86	5.13	6.30	7.59	8.57	8.86	10.00	11.37	11.67	12.75	-	15.00	
	2stdev	-	-	-	1.21	1.71	2.65	2.99	2.42	3.42	1.88	2.67	2.33	1.30	3.42	-	#####	
	CV (%)	-	-	-	19%	22%	26%	24%	16%	20%	11%	13%	10%	6%	13%	-	#####	17%
	Number of age readings	-	-	-	11	21	23	10	29	28	22	19	19	12	4	-	1	199
	Agreement with modal age	-	-	-	64%	43%	61%	40%	52%	46%	55%	37%	58%	50%	25%	-	100%	50%

Reader 8	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
GERM AC	Mean age recorded	-	-	-	3.18	4.14	5.14	6.20	7.55	8.50	9.41	10.47	11.58	12.25	12.50	-	12.00	
	2stdev	-	-	-	0.81	0.72	0.94	1.26	1.47	1.59	2.44	2.15	1.68	2.28	1.15	-	#####	
	CV (%)	-	-	-	13%	9%	9%	10%	10%	9%	13%	10%	7%	9%	5%	-	#####	10%
	Number of age readings	-	-	-	11	21	22	10	29	28	22	19	19	12	4	-	1	198
	Agreement with modal age	-	-	-	82%	86%	77%	90%	59%	43%	50%	42%	32%	42%	50%	-	0%	58%

Reader 9	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
S.AFR MK	Mean age recorded	-	-	-	3.18	4.10	5.13	6.00	7.45	8.32	9.09	9.84	10.72	11.18	11.67	-	9.00	
	2stdev	-	-	-	0.81	0.87	1.25	0.94	1.26	1.64	2.13	1.53	2.55	2.80	4.62	-	#####	
	CV (%)	-	-	-	13%	11%	12%	8%	8%	10%	12%	8%	12%	13%	20%	-	#####	11%
	Number of age readings	-	-	-	11	21	23	10	29	28	22	19	18	11	3	-	1	196
	Agreement with modal age	-	-	-	82%	81%	61%	80%	52%	64%	32%	58%	33%	45%	67%	-	0%	57%

Reader 10	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
-	Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	CV (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####
	Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

ALL READERS	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
	Mean age recorded	-	-	-	3.20	4.01	5.09	6.13	7.45	8.32	9.18	10.21	11.25	11.61	12.48	-	12.50	
	2stdev	-	-	-	0.94	1.22	1.67	1.81	2.48	2.37	2.46	2.72	2.50	3.11	3.22	-	4.00	
	CV (%)	-	-	-	15%	15%	16%	15%	17%	14%	13%	13%	11%	13%	13%	-	16%	14%
	Number of age readings	-	-	-	70	156	179	80	231	223	176	152	151	95	31	-	8	1552
	Agreement with modal age	-	-	-	74%	71%	66%	58%	53%	50%	48%	45%	48%	44%	48%	-	25%	54%

Table 3.5 HORSE MACKEREL OTOLITH EXCHANGE 1996 SET B (revised)

Divisions VIa, VIIb,e,h,j and VIIIa

Year	Sample	Fish no	Fish length	Catch month	NETH CK Reader 1	NETH SR Reader 2	SPAIN PA Reader 3	SPAIN IR Reader 4	PORT LS Reader 5	NORW HG Reader 6	IREL EB Reader 7	GERM AC Reader 8	PORT AMC Reader 9	- Reader 10	MODAL AGE	Age difference	Average
94	59	3	16.4	6	2	2	2	2	1	2	2	2	2	-	2	1	1.89
94	59	9	17.3	6	2	2	2	2	1	2	2	2	2	-	2	1	1.89
94	59	7	17.8	6	2	2	2	2	1	2	2	2	2	-	2	1	1.89
94	59	5	18.3	6	2	2	2	2	1	2	2	2	2	-	2	1	1.89
94	59	17	18.3	6	2	2	2	2	2	2	2	2	2	-	2	0	2.00
94	59	11	18.5	6	2	2	2	2	1	2	2	2	2	-	2	1	1.89
94	59	15	18.7	6	2	2	2	2	1	2	2	2	2	-	2	1	1.89
94	59	13	18.9	6	2	2	2	2	1	2	2	2	2	-	2	1	1.89
94	59	19	19.3	6	2	2	2	2	2	2	2	2	2	-	2	0	2.00
94	59	21	19.8	6	2	2	2	2	1	2	3	2	3	-	2	2	2.11
90	14	2	20.4	4	3	3	3	3	3	3	3	3	3	-	3	0	3.00
90	14	3	21.1	4	3	3	3	3	3	3	3	3	3	-	3	0	3.00
90	14	4	21.2	4	3	2	3	3	3	3	3	3	3	-	3	1	2.89
90	14	7	22.0	4	3	3	3	3	3	3	3	3	3	-	3	0	3.00
91	17	2	22.2	3	4	3	4	3	4	3	3	3	4	-	3	1	3.44
94	59	24	22.3	6	3	2	3	3	3	3	3	3	3	-	3	1	2.89
92	21	3	22.5	4	3	3	3	2	3	3	3	3	4	-	3	2	3.00
90	14	5	22.8	4	4	3	4	4	4	4	4	4	4	-	4	1	3.89
90	14	10	22.8	4	3	3	3	3	4	3	3	3	3	-	3	1	3.11
92	21	2	22.9	4	3	3	3	3	3	3	3	3	3	-	3	0	3.00
90	14	11	23.3	4	3	3	3	3	3	3	3	3	3	-	3	0	3.00
94	26	1	23.4	2	4	3	4	3	4	3	3	4	4	-	4	1	3.56
94	59	25	23.7	6	4	3	4	3	3	4	3	3	3	-	3	1	3.33
90	14	12	23.8	4	4	3	4	3	4	4	3	4	4	-	4	1	3.67
90	14	16	24.2	4	4	4	4	3	4	4	3	4	4	-	4	1	3.78
91	18	1	24.3	4	4	4	4	3	4	4	3	4	4	-	4	1	3.78
90	14	17	24.4	4	4	4	4	3	4	4	4	4	4	-	4	1	3.89
92	21	4	24.7	4	3	3	4	3	3	3	3	3	4	-	3	1	3.22
90	14	13	24.8	4	4	-	4	4	3	4	4	4	4	-	4	1	3.88
90	25	2	25.4	6	5	4	5	5	4	5	5	5	5	-	5	1	4.78
93	43	5	25.8	5	5	5	5	4	4	5	5	5	5	-	5	1	4.78
91	16	8	26.0	4	5	6	5	4	5	5	4	4	5	-	5	2	4.78
93	43	19	26.2	5	5	5	5	4	4	5	5	5	5	-	5	1	4.78
92	26	6	26.3	5	10	8	10	6	6	7	4	9	5	-	10	6	7.22
90	20	11	26.4	4	5	5	5	5	5	5	5	5	5	-	5	0	5.00
91	21	5	26.6	4	4	5	4	3	5	5	4	4	5	-	4	2	4.33
94	44	2	26.7	3	8	7	7	6	6	6	6	6	5	-	6	3	6.33
93	24	1	26.7	3	6	6	6	5	5	6	6	6	5	-	6	1	5.67
90	23	5	26.8	6	5	6	6	5	5	6	6	5	5	-	5	1	5.44
93	50	2	26.9	5	5	5	5	5	5	5	5	5	5	-	5	0	5.00
93	57	2	27.0	6	5	8	5	4	4	5	4	5	4	-	5	4	4.89
92	27	14	27.0	5	10	8	9	6	9	8	9	9	7	-	9	4	8.33
94	18	2	27.2	2	7	7	6	7	6	7	9	7	7	-	7	3	7.00
94	24	3	27.3	2	7	7	6	5	5	7	6	6	6	-	6	2	6.11
93	19	6	27.3	3	6	7	6	5	6	7	6	6	6	-	6	2	6.11
92	27	9	27.3	5	5	6	6	4	5	6	5	5	7	-	5	3	5.44
94	24	2	27.4	2	7	6	7	6	6	7	6	7	7	-	7	1	6.56
93	50	4	27.5	5	8	9	8	7	7	8	8	8	7	-	8	2	7.78
93	38	5	27.7	4	11	9	10	7	9	10	9	11	9	-	9	4	9.44
94	14	1	27.8	1	12	13	10	8	7	10	9	12	9	-	12	6	10.00
91	30	9	27.8	4	9	7	9	7	8	9	9	9	9	-	9	2	8.44
94	14	2	27.9	1	12	8	11	7	10	9	10	12	12	-	12	5	10.11
94	41	4	28.0	3	12	9	10	8	10	10	8	11	11	-	10	4	9.89
94	49	3	28.0	4	9	11	8	6	8	9	8	9	9	-	9	5	8.56
93	17	15	28.0	3	6	10	5	5	6	6	5	7	7	-	6	5	6.33
94	16	16	28.1	2	15	6	14	7	9	13	11	14	14	-	14	9	11.44
94	23	8	28.1	2	7	11	7	6	7	7	6	6	9	-	7	5	7.33
93	38	8	28.1	4	11	10	5	5	7	6	5	6	8	-	5	6	7.00
93	49	9	28.1	5	8	8	7	6	9	8	6	7	10	-	8	4	7.67
94	34	7	28.2	3	7	7	6	6	7	7	6	7	8	-	7	2	6.78
94	40	3	28.2	3	14	7	14	9	11	13	13	12	8	-	14	7	11.22
93	22	3	28.2	3	6	8	6	5	7	6	6	6	6	-	6	3	6.22
93	27	8	28.2	3	6	9	6	6	6	6	5	5	6	-	6	4	6.11
93	47	17	28.2	5	8	8	7	6	7	7	6	7	8	-	7	2	7.11
91	33	15	28.2	5	5	7	5	5	5	5	5	5	8	-	5	3	5.56
93	27	13	28.3	3	6	6	6	5	6	7	6	5	8	-	6	3	6.11
93	56	21	28.3	6	9	8	9	7	7	9	8	8	9	-	9	2	8.22
91	17	10	28.4	3	10	10	10	7	10	9	8	9	10	-	10	3	9.22
94	9	8	28.5	1	7	8	6	8	7	7	7	6	8	-	7	2	7.11
93	17	17	28.5	3	6	7	6	6	7	6	6	6	7	-	6	1	6.33
93	26	9	28.5	3	8	8	7	7	8	8	8	7	7	-	8	1	7.56
93	52	15	28.5	5	9	12	8	9	8	9	9	10	9	-	9	4	9.22
93	38	9	28.6	4	11	6	6	6	6	8	6	6	6	-	6	5	6.78
93	25	2	28.6	3	6	7	5	5	6	6	5	5	6	-	6	2	5.67
94	19	6	28.8	2	8	8	7	5	7	8	6	6	7	-	8	3	6.89
94	33	15	28.8	3	7	7	6	7	6	8	6	6	7	-	7	2	6.67
93	25	6	29.0	3	6	9	6	5	7	7	6	5	6	-	6	4	6.33
93	28	15	29.0	3	9	9	8	7	9	7	8	7	6	-	9	3	7.78
94	25	16	29.2	2	7	7	7	6	8	8	6	7	6	-	7	2	6.89
92	27	23	29.2	5	10	12	9	8	10	9	8	10	10	-	10	4	9.56
94	8	13	29.3	1	8	8	7	7	8	7	6	7	8	-	8	2	7.33
93	42	20	29.3	4	13	12	10	7	11	10	8	9	8	-	10	6	9.78
93	49	18	29.3	5	8	8	7	6	7	8	7	7	7	-	7	2	7.22
91	30	18	29.3	4	9	10	8	7	9	9	7	9	9	-	9	3	8.56
93	47	18	29.5	5	11	11	9	9	10	9	9	10	10	-	9	2	9.78
93	20	6	29.6	3	6	13	6	8	7	9	6	8	6	-	6	7	7.67
94	41	9	29.9	3	12	12	12	10	11	11	10	11	11	-	11	2	11.11
93	38	19	29.9	4	11	12	10	9	11	11	9	11	10	-	11	3	10.44
94	23	17	30.0	2	9	10	8	7	10	10	8	8	9	-	10	3	8.78
94	5	3	30.1	1	7	9	7	5	9	8	6	7	7	-	7	4	7.22
94	26	10	30.5	2	10	10	8	7	8	8	6	9	7	-	8	4	8.11
94	46	7	30.5	4	8	9	7	6	8	9	5	7	7	-	7	4	7.33
94	8	22	30.7	1	9	11	8	8	8	8	7	9	8	-	8	4	8.44
93	41	13	30.7	4	14	14	13	11	10	8	7	14	7	-	14	7	10.89
94	41	12	30.8	3	12	13	11	13	11	11	9	12	12	-	12	4	11.56
90	4	15	31.3	3	11	11	10	9	10	11	9	11	10	-	11	2	10.22
94	1	19	31.5	1	9	9	8	8	8	11	9	8	8	-	8	3	8.67
94	9	21	31.6	1	7	9	7	6	7	7	6	6	7	-	7	3	6.89
94	10	19	31.6	1	8	9	7	7	8	10	7	7	8	-	7	3	7.89
93	23	6	31.8	3	17	10	16	14	9	12	12	16	7	-	16	10	12.56

91	24	20	32.7	4	12	13	11	11	10	12	11	11	10	-	11	3	11.22
93	3	17	33.0	1	14	16	11	10	11	12	10	12	10	-	10	6	11.78
92	29	10	33.1	6	10	11	9	9	10	10	8	9	9	-	9	3	9.44
91	1	22	33.1	1	10	12	9	9	10	11	8	10	9	-	10	4	9.78
92	28	14	33.2	5	10	11	9	9	9	10	8	10	9	-	9	3	9.44
89	2	13	33.2	2	10	11	10	7	11	11	9	10	10	-	10	4	9.89
94	56	5	33.3	5	11	10	10	8	11	11	9	11	10	-	11	3	10.11
90	5	24	33.3	3	11	11	10	10	12	11	8	10	10	-	10	4	10.33
89	2	15	33.3	2	10	12	9	8	11	10	7	9	10	-	10	5	9.56
94	44	24	33.5	3	18	16	16	13	15	11	8	15	10	-	16	10	13.56
94	52	16	33.6	4	15	16	15	12	15	9	-	14	15	-	15	7	13.88
94	41	21	33.7	3	12	13	11	9	12	13	8	12	11	-	12	5	11.22
91	2	23	33.8	3	28	25	27	12	17	25	13	26	25	-	25	16	22.00
94	5	16	33.9	1	15	14	13	11	12	12	10	13	17	-	13	7	13.00
93	4	25	34.1	1	14	12	13	10	12	12	9	13	11	-	12	5	11.78
89	2	17	34.2	2	13	14	12	8	13	11	9	13	14	-	13	6	11.89
94	57	14	34.3	5	15	18	13	12	15	13	12	15	14	-	15	6	14.11
90	7	25	34.4	3	11	11	9	8	12	10	9	8	9	-	9	4	9.67
92	4	18	34.5	2	13	12	12	11	12	12	11	13	11	-	12	2	11.89
94	57	16	34.6	5	14	13	11	11	14	12	10	12	12	-	12	4	12.11
94	47	17	34.7	4	15	13	15	13	16	13	10	16	11	-	13	6	13.56
94	6	20	34.7	1	15	21	15	12	14	16	10	18	12	-	15	11	14.56
94	54	25	34.7	4	9	12	8	8	11	9	8	8	8	-	8	4	9.00
93	3	19	34.8	1	14	16	12	11	14	12	8	13	13	-	14	8	12.56
94	51	19	35.1	4	15	13	13	12	16	13	12	13	14	-	13	4	13.44
91	29	25	35.1	4	21	19	20	18	19	17	12	17	17	-	17	9	17.78
91	7	22	35.2	3	12	15	10	10	13	12	11	11	12	-	12	5	11.78
91	4	23	35.3	3	12	15	11	9	12	12	8	11	11	-	12	7	11 22
89	3	24	35.3	2	13	15	11	10	13	12	10	12	12	-	12	5	12.00
90	4	23	35.4	3	11	13	10	6	15	13	8	10	11	-	11	9	10.78
92	4	22	35.5	2	13	14	12	10	14	11	11	12	13	-	13	4	12.22
91	5	23	35.7	3	12	13	11	14	14	12	10	12	10	-	12	4	12.00
94	36	23	35.8	3	19	20	17	15	19	11	13	16	17	-	19	9	16.33
94	51	20	35.9	4	13	17	12	11	14	16	11	13	13	-	13	6	13.33
94	55	10	35.9	5	23	23	22	9	26	12	12	22	18	-	23	17	18.56
94	31	25	36.0	3	15	14	15	9	15	17	14	14	15	-	15	8	14.22
92	4	20	36.0	2	13	16	12	12	13	14	9	12	9	-	12	7	12.22
94	11	26	36.1	1	15	15	13	11	15	13	12	16	12	-	15	5	13.56
93	45	15	36.3	5	29	24	28	19	23	15	16	25	16	-	16	14	21.67
90	9	21	36.4	3	21	26	20	16	21	17	17	20	19	-	21	10	19.67
93	3	24	36.4	1	14	15	12	9	16	15	12	11	12	-	12	7	12.89
89	4	15	36.5	3	13	13	12	8	14	13	14	11	11	-	13	6	12 11
93	36	22	36.8	4	30	27	30	18	28	20	15	28	26	-	30	15	24.67
91	16	24	36.8	4	-	-	-	-	-	-	-	-	-	-			
89	4	13	36.8	3	-	-	-	-	-	-	-	-	-	-			
90	9	23	37.0	3	27	20	17	16	23	17	14	21	18	-	17	13	19.22
93	3	25	37.2	1	14	16	12	10	14	12	10	12	13	-	12	6	12.56
94	22	25	37.3	2	18	17	17	15	18	17	16	16	16	-	17	3	16.67
89	4	16	37.3	3	13	18	12	10	14	14	13	13	11	-	13	8	13.11
91	9	22	37.4	3	14	18	13	11	17	13	12	13	13	-	13	7	13.78
94	55	17	37.6	5	18	19	18	12	19	15	10	17	16	-	18	9	16.00
94	29	25	37.8	3	25	21	24	17	23	17	13	21	21	-	21	12	20.22
91	21	24	37.9	4	21	19	21	18	22	18	15	22	20	-	21	7	19.56
94	38	25	38.5	3	15	15	14	11	15	13	13	14	15	-	15	4	13.89
94	55	20	38.5	5	25	28	26	15	23	20	15	24	21	-	15	13	21.89
91	9	24	38.6	3	14	15	14	11	13	13	9	14	13	-	14	6	12.89
93	45	20	38.7	5	24	25	22	18	22	20	13	23	21	-	22	12	20.89
93	45	21	38.8	5	24	17	22	11	22	17	18	21	20	-	17	13	19.11
93	20	25	39.7	3	18	16	17	13	18	15	14	17	15	-	18	5	15.89
91	3	25	40.5	3	20	21	20	17	21	18	19	20	19	-	20	4	19.44
93	45	25	41.8	5	24	24	23	15	23	19	17	22	23	-	23	9	21.11
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
				Total read	159	158	159	159	159	159	158	159	159	0			
				Total NOT read	0	1	0	0	0	0	1	0	0	159			
				Empty rows	41	41	41	41	41	41	41	41	41	41			

HORSE MACKEREL OTOLITH EXCHANGE 1996 SET B (revised)

Table 3.6 **The mean age recorded, 2stdev, the number of age readings and the agreement with modal age are presented by modal age for each reader and for all readers combined. The total number of age readings and the weighted means of CV and agreement is given for age groups 0-15. Precision is indicated by CV and accuracy by agreement.**

Reader 1	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
NETH CK	Mean age recorded	-	-	2.00	3.17	4.00	5.55	6.62	7.31	8.56	9.75	10.82	11.33	12.79	13.78	14.20	16.43	
	2stdev	-	-	0.00	0.78	0.00	3.62	2.89	0.96	1.45	1.73	3.07	1.03	1.79	1.94	0.89	7.56	
	CV (%)	-	-	0%	12%	0%	33%	22%	7%	8%	9%	14%	5%	7%	7%	3%	23%	11%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	7	140
	Agreement with modal age	-	-	100%	83%	100%	91%	77%	69%	56%	50%	55%	67%	50%	56%	60%	86%	71%

Reader 2	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
NETH SR	Mean age recorded	-	-	2.00	2.83	3.71	6.09	7.85	8.08	9.22	9.83	11.18	11.83	13.50	14.89	11.60	18.14	
	2stdev	-	-	0.00	0.78	1.51	3.40	3.99	2.64	2.96	3.17	4.18	2.34	4.21	4.29	9.44	9.89	
	CV (%)	-	-	0%	14%	20%	28%	25%	16%	16%	16%	19%	10%	16%	14%	41%	27%	18%
	Number of age readings	-	-	10	12	7	11	13	13	9	12	11	6	14	9	5	7	139
	Agreement with modal age	-	-	100%	83%	43%	36%	23%	31%	44%	17%	18%	17%	14%	33%	20%	29%	37%

Reader 3	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
SPAIN PA	Mean age recorded	-	-	2.00	3.25	4.00	5.18	5.92	6.69	7.56	8.75	9.64	10.50	11.29	12.67	13.40	15.86	
	2stdev	-	-	0.00	0.90	0.00	0.81	0.99	0.96	1.05	1.24	1.62	1.67	1.65	2.00	1.79	9.12	
	CV (%)	-	-	0%	14%	0%	8%	8%	7%	7%	7%	8%	8%	7%	8%	7%	29%	8%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	7	140
	Agreement with modal age	-	-	100%	75%	100%	82%	77%	69%	56%	58%	55%	17%	29%	33%	60%	43%	62%

Reader 4	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
SPAIN IR	Mean age recorded	-	-	2.00	2.92	3.25	4.55	5.54	6.31	7.00	7.58	7.91	8.83	10.21	10.44	9.80	11.71	
	2stdev	-	-	0.00	0.58	0.93	1.04	1.75	1.50	2.00	2.33	2.60	3.44	3.78	3.33	3.58	3.60	
	CV (%)	-	-	0%	10%	14%	11%	16%	12%	14%	15%	16%	19%	18%	16%	18%	15%	14%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	7	140
	Agreement with modal age	-	-	100%	92%	25%	55%	31%	23%	33%	33%	18%	17%	7%	11%	0%	14%	35%

Reader 5	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
PORT LS	Mean age recorded	-	-	1.20	3.17	4.00	4.82	6.15	7.15	8.22	9.00	10.18	11.33	12.36	14.44	11.40	16.00	
	2stdev	-	-	0.84	0.78	1.07	1.75	1.38	1.80	2.40	2.56	3.07	3.72	4.27	3.18	4.15	6.22	
	CV (%)	-	-	35%	12%	13%	18%	11%	13%	15%	14%	15%	16%	17%	11%	18%	19%	16%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	7	140
	Agreement with modal age	-	-	20%	83%	75%	55%	54%	46%	56%	42%	45%	50%	29%	11%	20%	71%	47%

Reader 6	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
NORW HG	Mean age recorded	-	-	2.00	3.08	4.00	5.27	6.69	7.69	8.33	9.08	10.00	11.50	12.00	12.89	11.80	14.43	
	2stdev	-	-	0.00	0.58	1.07	0.93	1.89	1.89	2.24	1.80	2.68	1.67	2.94	3.07	4.34	7.10	
	CV (%)	-	-	0%	9%	13%	9%	14%	12%	13%	10%	13%	7%	12%	12%	18%	25%	12%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	7	140
	Agreement with modal age	-	-	100%	92%	75%	73%	54%	54%	67%	50%	36%	67%	57%	44%	0%	0%	58%

Reader 7	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
IREL EB	Mean age recorded	-	-	2.10	3.00	3.50	4.91	5.77	6.38	7.11	8.42	7.82	9.33	9.71	11.33	9.60	12.67	
	2stdev	-	-	0.63	0.00	1.07	1.08	0.88	1.92	2.33	1.34	2.94	2.07	2.28	3.16	4.82	3.50	
	CV (%)	-	-	15%	0%	15%	11%	8%	15%	16%	8%	19%	11%	12%	14%	25%	14%	12%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	6	139
	Agreement with modal age	-	-	90%	100%	50%	73%	77%	23%	33%	50%	9%	17%	7%	11%	0%	17%	43%

Reader 8	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
GERM AC	Mean age recorded	-	-	2.00	3.00	4.00	5.00	5.92	6.69	7.67	9.08	9.73	10.83	11.93	13.00	13.40	16.14	
	2stdev	-	-	0.00	0.00	0.00	0.89	1.72	0.96	2.00	2.17	2.21	0.82	1.23	2.65	1.79	7.16	
	CV (%)	-	-	0%	0%	0%	9%	15%	7%	13%	12%	11%	4%	5%	10%	7%	22%	8%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	7	140
	Agreement with modal age	-	-	100%	100%	100%	82%	54%	69%	33%	42%	36%	83%	64%	67%	60%	14%	65%

Reader 9	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
PORT AMC	Mean age recorded	-	-	2.10	3.25	4.13	5.64	6.15	7.38	7.78	8.67	9.27	10.33	11.21	13.00	11.00	14.86	
	2stdev	-	-	0.63	0.90	0.71	2.72	1.60	1.54	1.94	2.15	3.24	1.03	2.38	3.87	6.48	6.05	
	CV (%)	-	-	15%	14%	9%	24%	13%	10%	12%	12%	17%	5%	11%	15%	29%	20%	14%
	Number of age readings	-	-	10	12	8	11	13	13	9	12	11	6	14	9	5	7	140
	Agreement with modal age	-	-	90%	75%	88%	64%	62%	54%	44%	75%	55%	33%	43%	33%	20%	43%	58%

Reader 10	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
-	Mean age recorded	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	2stdev	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	CV (%)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####
	Number of age readings	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
	Agreement with modal age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	#####

ALL READERS	Modal age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
	Mean age recorded	-	-	1.93	3.07	3.85	5.22	6.29	7.08	7.94	8.91	9.62	10.65	11.67	12.94	11.80	15.18	
	2stdev	-	-	0.66	0.71	0.99	2.20	2.42	1.97	2.42	2.42	3.55	2.81	3.63	3.99	5.34	7.56	
	CV (%)	-	-	17%	12%	13%	21%	19%	14%	15%	14%	18%	13%	16%	15%	23%	25%	16%
	Number of age readings	-	-	90	108	71	99	117	117	81	108	99	54	126	81	45	62	1258
	Agreement with modal age	-	-	89%	87%	73%	68%	56%	49%	47%	46%	36%	41%	33%	33%	29%	35%	53%

Table 5.1 Horse Mackerel Otolith SET G (WKHMO, Lowestoft, 15-19 January 1999)

Otol. no	RIVO Sample	Fish no	Fish length	Landing month	S.Afr MK Reader 1	Norw HG Reader 2	Spain PA Reader 3	Spain QP Reader 4	Spain IR Reader 5	Port LS Reader 6	Port AMC Reader 7	Irel LB Reader 8	Irel EM Reader 9	Neth SR Reader 10	Neth BC Reader 11	Germ AC Reader 12	Germ GG Reader 13	Denm AT Reader 14	Eng PW Reader 15	ACTUAL AGE	Age difference	Average
1	85-004	26	20.7	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	0	3.00
2	85-003	41	21.6	3	3	3	3	3	3	3	3	3	3	2	3	3	2	2	3	3	1	2.80
3	86-001	2	22.1	2	4	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	1	3.13
4	85-005	29	22.8	4	3	3	3	3	3	3	4	3	3	2	3	3	3	3	5	3	3	3.13
5	85-005	21	22.8	4	3	3	4	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3.00
6	85-005	33	23.3	4	3	3	3	3	3	3	3	3	4	2	3	3	3	3	3	3	2	3.00
7	86-014	5	23.5	5	4	4	3	4	3	4	4	4	4	3	4	4	3	4	4	4	1	3.73
8	85-005	34	23.7	4	3	3	4	2	3	3	4	3	2	3	3	2	2	2	3	3	2	2.80
9	86-001	4	23.8	2	4	5	3	4	3	4	3	4	3	3	3	3	3	3	3	4	2	3.40
10	87-006	2	23.8	3	5	5	5	6	4	5	6	4	6	4	6	6	4	5	6	5	2	5.13
11	86-003	9	24.0	2	4	4	4	4	3	4	4	5	4	3	4	5	4	3	4	4	2	3.93
12	86-010	7	24.0	4	4	4	4	4	4	4	4	4	4	3	4	5	4	4	4	4	2	4.00
13	86-009	4	24.0	4	4	4	4	4	4	4	4	4	4	3	4	5	5	4	4	4	2	4.07
14	86-006	1	24.1	3	4	4	4	5	4	4	5	4	4	4	5	4	4	4	4	4	1	4.20
15	86-011	10	24.2	4	4	4	5	6	6	4	6	6	4	4	5	4	5	4	4	4	2	4.60
16	87-005	1	24.3	3	5	5	5	5	4	5	5	5	5	4	5	5	5	4	4	5	1	4.73
17	86-011	8	24.4	4	4	4	4	4	4	4	6	5	4	3	4	5	5	3	4	4	3	4.20
18	86-007	9	24.4	4	4	4	4	4	4	4	6	4	3	3	5	4	5	4	4	4	3	4.13
19	86-014	13	24.4	5	4	4	4	5	5	4	6	4	5	4	5	4	4	3	4	4	3	4.33
20	86-010	6	24.5	4	4	5	4	4	4	4	5	4	4	3	4	5	5	4	4	4	2	4.20
21	86-007	11	24.8	4	4	4	5	5	4	4	4	5	4	3	5	4	5	4	4	4	2	4.27
22	86-007	15	24.9	4	4	4	4	4	4	4	4	4	5	3	4	4	5	4	4	4	2	4.07
23	87-005	5	25.3	3	5	5	4	4	5	4	5	5	5	4	4	5	5	4	5	5	1	4.60
24	86-006	6	25.4	3	5	4	4	4	5	5	5	4	6	4	5	4	5	4	4	4	2	4.53
25	87-004	4	25.6	3	5	5	5	5	5	5	5	5	5	5	5	5	5	4	5	5	1	4.93
26	87-006	11	25.6	3	5	5	5	4	5	5	5	5	5	5	5	5	5	4	5	5	1	4.87
27	89-009	2	25.6	3	7	7	7	5	7	6	7	7	7	5	8	7	7	8	8	7	3	6.87
28	86-001	15	25.7	2	4	5	5	4	5	5	5	5	5	5	5	4	6	4	5	4	2	4.80
29	88-006	7	26.0	2	6	6	6	5	6	6	6	6	5	5	6	6	7	6	6	6	2	5.87
30	88-004	2	26.0	2	6	6	5	5	6	6	6	6	6	5	6	6	6	5	6	6	1	5.73
31	88-003	6	26.1	2	6	6	6	7	6	6	6	7	6	5	7	6	6	5	6	6	2	6.07
32	87-008	15	26.1	3	5	6	5	5	5	5	6	6	5	6	6	5	6	5	5	5	1	5.40
33	87-007	11	26.2	3	5	5	4	4	5	5	7	6	4	5	7	5	5	5	5	5	3	5.13
34	87-007	12	26.2	3	5	5	5	5	5	5	6	5	5	5	6	5	5	5	5	5	1	5.13
36	87-008	10	26.3	3	5	5	5	5	4	6	7	5	5	6	6	5	6	5	6	5	3	5.40
36	87-008	14	26.3	3	5	5	4	5	5	4	6	5	5	6	6	5	5	4	5	5	2	5.00
37	91-004	2	26.3	3	9	6	8	8	8	8	8	6	8	8	8	8	6	6	10	9	4	7.67
38	86-014	23	26.3	5	4	5	4	5	5	5	6	4	6	6	6	5	6	5	4	4	2	5.07
39	88-001	20	26.4	2	6	5	6	5	7	6	7	5	5	6	7	6	6	6	6	6	2	5.93
40	87-008	12	26.5	3	5	5	5	4	5	6	5	4	5	5	8	6	5	4	5	5	4	5.13
41	87-002	12	26.6	3	5	5	5	5	5	6	6	5	5	5	6	5	6	4	5	5	2	5.20
42	87-005	8	26.6	3	5	5	5	5	5	6	6	5	5	6	6	5	6	4	5	5	2	5.27
43	91-003	4	26.7	2	8	8	7	8	8	7	8	9	9	6	9	7	7	8	8	9	3	7.80
44	87-004	10	26.7	3	5	5	5	4	5	7	6	4	5	6	7	5	7	5	6	5	3	5.47
45	86-005	6	26.7	3	4	4	4	4	4	5	5	4	4	7	7	4	7	4	4	4	3	4.73
46	91-005	2	26.7	3	9	8	7	7	8	7	8	8	8	7	9	6	9	7	8	9	3	7.73
47	91-001	1	26.8	2	8	8	8	7	7	8	7	8	7	8	7	8	9	6	7	9	3	7.53
48	91-002	3	26.8	2	9	9	8	7	8	8	9	8	9	7	9	7	9	8	4	9	5	7.93
49	90-002	1	26.8	2	8	8	7	8	8	8	8	7	8	7	8	7	9	5	8	8	4	7.60
50	88-001	18	26.8	2	6	6	6	5	5	7	6	7	5	6	5	6	9	6	7	6	4	6.13
51	88-003	10	26.8	2	6	6	6	6	4	5	6	7	6	6	8	6	8	6	6	6	4	6.13
52	91-002	7	27.0	2	9	7	8	8	7	6	9	8	8	7	7	10	9	10	4	9	6	7.80
53	92-003	5	27.0	2	9	9	9	6	7	6	11	9	8	8	6	9	8	7	11	10	5	8.20
54	88-004	22	27.1	2	6	5	6	6	5	6	7	6	6	7	6	6	8	5	7	6	3	6.13
55	88-004	15	27.1	2	5	6	5	6	5	5	8	6	5	7	5	6	9	6	6	6	4	6.00
56	93-001	3	27.2	1	9	9	10	7	9	7	7	9	9	9	11	7	9	9	8	11	4	8.60
57	88-006	12	27.2	2	6	7	6	7	6	6	9	7	9	7	6	6	9	7	8	6	3	7.07
58	93-001	2	27.3	1	10	10	10	7	8	6	10	7	9	8	10	8	10	6	10	11	4	8.60
59	91-005	3	27.3	3	9	10	9	6	7	7	10	8	9	8	9	8	9	8	8	9	4	8.33
60	93-008	17	27.4	1	11	11	11	10	11	10	11	11	10	9	12	11	10	10	11	11	3	10.60
61	88-006	14	27.4	2	6	6	5	7	6	7	7	7	7	7	7	6	9	5	6	6	4	6.53
62	94-001	1	27.5	1	11	10	11	9	10	8	10	11	9	7	10	10	10	10	11	12	4	9.80
63	91-002	6	27.5	2	9	8	8	8	8	7	9	10	8	8	8	8	9	9	7	9	3	8.27
64	92-005	5	27.5	2	9	10	9	8	9	8	10	10	9	8	9	9	11	9	10	10	3	9.20
65	87-005	10	27.7	3	5	5	6	5	5	7	8	5	5	6	5	5	8	5	5	5	3	5.67
66	87-008	18	27.7	3	5	5	5	4	5	5	7	7	4	7	5	5	7	6	5	5	3	5.47
67	93-008	18	27.8	1	11	7	10	9	9	7	10	12	10	8	9	10	8	11	9	11	5	9.33
68	89-007	3	27.8	3	7	7	6	7	7	7	9	9	7	7	7	7	8	10	7	7	4	7.47
69	90-005	8	27.8	3	8	8	7	9	7	7	8	8	7	7	8	8	9	8	8	8	2	7.80
70	90-007	4	27.8	3	5	9	7	7	7	7	9	10	9	8	8	8	9	9	8	8	5	8.00
71	88-005	13	27.9	2	6	7	5	5	6	7	6	5	6	7	6	7	8	6	6	6	3	6.20
72	89-008	8	28.2	3	7	7	6	5	7	7	7	6	6	8	7	6	8	6	7	7	3	6.67
73	94-005	1	28.3	1	9	11	11	9	10	10	8	11	11	9	11	10	10	9	10	12	3	9.93
74	92-003	12	28.3	2	9	10	9	9	9	8	8	10	9	10	9	10	9	11	8	10	3	9.20
75	89-006	5	28.3	3	7	7	6	7	6	7	7	7	7	8	7	8	8	5	7	7	3	6.93
76	89-008	6	28.3	3	7	7	6	7	7	7	7	7	8	9	7	7	8	9	7	7	3	7.33
77	95-002	6	28.4	1	8	13	12	8	11	12	10	13	11	12	12	12	9	13	8	13	5	10.93
78	90-003	10	28.4	2	8	8	7	7	8	8	8	7	8	9	8	7	9	10	8	8	3	8.00
79	88-002	17	28.4	2	6	6	6	6	6	8	6	8	6	8	6	6	9	6	8	6	3	6.73
80	94-001	8	28.5	1	11	11	10	9	9	9	10	11	9	10	9	9	10	14	10	12	5	10.07
81	94-002	5	28.5	1	9	11	11	10	10	9	11	11	9	9	11	11	12	8	10	12	4	10.13
82	93-009	25	28.5	1	11	12	10	11	10	10	11	10	10	9	11	10	10	8	11	11	4	10.27
83	92-002	10	28.6	2	10	11	10	11	10	10	10	11	9	8	10	9	10	10	10	10	3	9.93
84	95-007	4	28.7	1	13	13	12	11	12	11	13	11	12	9	12	11	9	12	12	13	4	11.53
85	95-004	3	28.7	1	11	13	13	10	12	11	11	11	11	10	13	12	12	13	10	13	3	11.53
86	93-005	10	28.7	1	11	12	10	9	10	9	10	11	11	10	12	10	9	9	10	11	3	10.20
87	92-003	17	28.7	2	9	11	9	10	9	9	10	11	8	9	9	8	10	10	8	10	3	9.33
88	92-006	11	28.7	3	9	11	9	9	9	9	9	9	9	8	9	8	9	10	8	10	3	9.00
89	95-001	8	28.8	1	12	11	11	11	11	10	13	8	11	10	12	11	11	11	11	13	5	10.93
90	92-003	13	28.8	2	10	10	10	8	9	10	11	10	9	9	7	10	9	10	9	10	4	9.40
91	87-001	4	28.8	2	5	5	5	6	5	5	7	8	5	8	5	6	8	6	6	5	3	6.00
92	94-002	6	28.9	1	11	11	12	11	11	9	10	12	11	9	7	10	9	12	10	12	5	10.33
93	95-002	8	28.9	1	12	11	11	11	13	9	11	12	12	10	10	10	10	9	11	13	4	10.80
94	92-005	13	28.9	2	10	8	10	11	11	10	10	12	11	8	10	10	12	11	11	10	4	10.33
95	89-005	4	28.9	3	7	6	7	7	7	6	6	9	6	9	8	7	8	8	7	7	3	7.07
96	93-005	13	29.0	1	7	9	12	9	10	9	11	10	11	9	11	11	10	11	9	11	5	9.93
97	89-008	14	29.0	3	7	6	7	7	7	7	7	7	8	10	8	8	9	8	7	7	4	7.53
98	87-004	20	29.0	3	5	4	5	6	6	7	6	5	5	8	6	6	8	6	6	5	4	5.93
99	87-001	5	29.1	2	5	6	5	8	5	7	8	8	8	8	6	7	8	7	6	5	3	6.80
100	89-005	9	29.1	3	7	7	6	7	7	8	7	7	6	9	7	7	8	8	7	7	3	7.20

101	88-005	24	29.2	2	6	8	6	7	5	7	7	6	8	9	6	7	8	7	6	8	4	6.73
102	91-005	9	29.2	3	8	9	8	8	8	8	9	8	9	8	8	9	10	10	9	9	2	8.67
103	91-007	8	29.2	3	9	9	9	8	8	8	8	9	10	9	8	9	10	8	9	9	2	8.73
104	90-003	14	29.3	2	8	8	8	8	8	8	8	9	8	9	7	8	10	7	8	8	3	8.13
105	89-005	8	29.3	3	7	7	6	6	6	7	6	6	6	8	7	8	10	8	7	7	4	7.00
106	88-008	22	29.4	2	7	7	6	5	7	6	6	7	7	9	7	7	9	7	8	6	4	7.00
107	90-003	16	29.4	2	7	7	9	7	8	7	8	10	9	9	7	8	11	8	7	8	4	8.13
108	94-006	1	29.6	1	8	10	11	9	9	8	10	8	10	10	13	9	11	11	9	12	5	9.73
109	88-003	20	29.6	2	6	7	6	7	7	6	7	9	10	10	7	6	8	7	6	6	4	7.27
110	91-001	11	29.6	2	9	9	8	11	8	8	9	10	10	9	7	8	11	8	9	9	4	8.93
111	90-003	12	29.7	2	-	8	8	7	8	8	9	7	8	9	8	7	8	7	7	8	2	7 79
112	91-004	8	29.7	3	9	8	8	9	9	8	9	9	9	11	8	8	9	9	9	9	3	8.80
113	93-001	8	29.8	1	10	8	11	9	9	11	9	8	9	9	10	8	10	9	9	11	3	9.27
114	95-008	13	29.8	1	11	9	12	11	12	11	12	9	12	10	12	12	11	8	12	13	4	10.93
115	89-007	14	29.8	3	7	7	8	7	7	10	8	7	7	8	7	7	9	9	7	7	3	7.67
116	95-003	16	29.9	1	11	12	11	11	12	10	10	10	12	11	11	10	10	11	14	13	4	11.07
117	91-006	7	30.1	3	9	9	9	9	9	9	10	8	8	9	8	8	10	12	8	9	4	9.00
118	91-004	11	30.2	3	9	8	8	9	9	10	9	8	9	11	8	7	11	9	8	9	4	8.87
119	89-005	6	30.2	3	7	9	7	8	8	10	9	9	9	12	8	7	9	8	8	7	5	8.53
120	92-006	20	30.2	3	10	10	10	11	11	11	10	8	10	10	10	10	9	9	10	10	3	9.93
121	89-006	19	30.3	3	7	7	7	8	6	9	7	7	8	10	8	8	8	9	8	7	4	7.80
122	89-007	16	30.3	3	7	7	7	7	6	7	7	7	9	9	7	7	10	7	7	7	4	7.40
123	95-007	18	30.4	1	9	12	12	9	11	11	9	13	12	13	12	12	11	10	10	13	4	11.07
124	95-004	10	30.4	1	11	12	13	11	12	9	10	11	11	12	11	10	11	11	10	13	4	11.00
125	93-002	20	30.4	1	11	10	10	9	6	10	10	11	9	11	9	9	11	10	10	11	5	9.73
126	90-002	14	30.4	2	8	9	8	7	9	9	9	8	9	10	8	8	9	8	8	8	3	8.47
127	89-001	17	30.6	2	7	7	7	7	6	8	8	8	9	10	8	8	9	8	8	7	4	7.87
128	92-007	13	30.8	3	10	10	9	10	11	9	10	8	8	11	10	10	10	9	10	10	3	9.67
129	92-007	12	30.8	3	10	10	10	9	9	9	9	10	10	13	9	9	10	7	9	10	6	9 53
130	89-001	19	31.0	2	7	8	7	7	6	7	8	6	9	11	8	8	10	6	7	7	5	7.67
131	91-006	9	31.0	3	9	9	9	8	9	9	8	10	9	11	9	8	9	11	9	9	3	9.20
132	94-002	17	31.1	1	13	12	12	12	11	12	11	12	12	12	11	11	12	13	11	12	2	11.80
133	95-001	25	31.2	1	13	12	13	11	11	11	12	12	12	13	11	11	11	12	11	13	2	11.73
134	94-008	4	31.3	1	11	11	12	11	11	12	11	10	12	12	12	10	12	12	11	12	2	11.33
135	95-001	23	31.6	1	12	12	11	10	9	12	10	12	11	13	10	10	10	9	11	13	4	10.80
136	91-001	18	31.7	2	9	8	8	10	9	9	10	11	9	11	10	8	10	9	8	9	3	9.27
137	91-004	14	31.7	3	9	8	8	10	9	10	9	9	11	10	9	9	9	9	9	9	3	9.20
138	91-005	14	31.7	3	9	11	9	9	8	10	9	10	9	11	8	9	10	9	8	9	3	9.27
139	95-004	15	31.8	1	11	10	11	10	9	11	10	11	10	12	10	12	10	10	10	13	3	10.47
140	90-003	23	31.8	2	8	7	8	9	8	10	8	8	8	10	8	9	9	9	8	8	3	8.47
141	89-002	6	31.8	2	7	6	6	8	7	9	8	6	7	11	7	7	12	7	7	7	6	7.67
142	89-003	12	31.8	2	7	7	7	7	7	9	7	7	10	9	7	7	10	8	7	7	3	7 73
143	90-006	7	31.8	3	8	7	7	8	8	9	8	8	12	10	8	8	10	8	7	8	5	8 40
144	93-008	2	32.0	1	10	8	10	9	7	11	8	11	12	13	10	10	12	10	9	11	6	10.00
145	92-007	20	32.1	3	10	8	8	9	8	10	9	9	11	12	8	10	12	10	10	10	4	9.60
146	93-007	12	32.2	1	11	9	10	9	10	11	10	11	11	10	9	11	12	13	9	11	4	10 40
147	94-006	8	32.2	1	12	11	11	11	11	11	11	13	12	11	11	10	11	13	10	12	3	11.27
148	94-003	9	32.4	1	12	11	12	11	9	11	10	13	12	12	11	11	12	10	10	12	4	11 13
149	94-005	6	32.5	1	12	12	11	11	11	11	10	10	11	12	9	9	12	11	11	12	3	10 87
150	91-004	17	32.5	3	9	9	8	9	9	9	9	8	9	11	9	9	11	9	9	9	3	9.13
151	94-005	11	32.7	1	12	12	11	11	11	12	12	14	12	13	13	10	12	12	11	12	4	11.87
152	92-001	14	32.9	2	9	10	9	9	9	10	11	13	11	11	8	9	11	10	10	10	5	10.00
153	91-004	19	32.9	3	9	10	9	9	9	8	10	10	12	11	9	9	11	11	9	9	4	9.73
154	93-007	16	33.0	1	11	10	10	10	9	10	10	10	10	11	10	10	10	10	9	11	2	10 00
155	91-006	13	33.0	3	9	9	9	10	10	11	9	10	11	10	10	8	10	11	9	9	3	9.73
156	94-004	11	33.1	1	12	12	11	14	12	14	12	12	13	12	11	9	9	11	11	12	5	11.67
157	92-005	24	33.1	2	10	10	9	10	9	11	9	11	12	11	9	8	10	9	8	10	4	9 73
158	94-004	10	33.2	1	13	11	11	14	11	12	12	13	12	12	10	10	12	12	11	12	4	11 73
159	93-001	15	33.2	1	11	10	11	12	11	10	11	11	11	11	10	10	10	10	9	11	3	10 53
160	92-005	25	33.2	2	11	11	10	11	11	12	11	13	11	11	10	9	11	11	9	10	4	10.80
161	91-005	20	33.2	3	9	8	9	10	9	9	10	8	12	9	11	9	11	10	9	9	4	9 53
162	95-005	17	33.3	1	13	9	12	12	10	11	10	9	13	12	12	13	12	12	10	13	4	11.33
163	95-007	23	33.3	1	12	10	13	12	11	11	10	9	11	12	11	13	12	10	11	13	4	11.20
164	94-005	15	33.3	1	12	10	13	11	12	12	11	10	12	14	12	12	13	13	11	12	4	11.87
165	94-005	14	33.5	1	11	11	12	10	10	11	10	10	11	12	.13	11	12	12	10	12	3	11 07
166	91-004	20	33.5	3	9	9	10	8	9	9	10	10	9	11	12	11	12	9	9	9	4	9.80
167	95-005	18	33.6	1	12	11	11	10	11	10	9	11	12	15	12	15	14	13	10	13	6	11 73
168	94-008	17	33.9	1	12	11	12	11	11	11	11	9	11	12	12	13	15	11	11	12	6	11.53
168	94-008	15	34.7	1	10	10	11	9	9	12	10	9	12	12	11	12	12	11	9	12	3	10.60
170	93-003	21	34.8	1	10	10	10	10	9	11	9	9	11	11	11	12	12	10	10	11	3	10.33
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				Total read	169	170	170	170	170	170	170	170	170	170	170	170	170	170	170			
				Total NOT read	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
				Empty rows	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30			

Horse Mackerel Otolith SET G (WKHMO, Lowestoft, 15-19 January 1999)

Table 5.2 The mean age recorded, 2stdev, the number of age readings and the agreement with actual age are presented by actual age for each reader and for all readers combined. The total number of age readings and the weighted means of CV and agreement are given for age groups 0-15. Precision is indicated by CV and accuracy by agreement.

Reader 1	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
S.Afr MK	Mean age recorded	-	-	-	3.00	4.06	5.00	6.00	7.00	7.56	8.91	9.67	10.29	11.17	11.40	-	-	
	2stdev	-	-	-	0.00	0.47	0.00	0.76	0.00	2.03	0.58	1.23	2.28	2.77	2.81	-	-	
	CV(%)	-	-	-	0%	6%	0%	6%	0%	13%	3%	6%	11%	12%	12%	-	-	6%
	Number of age readings	-	-	-	6	18	19	15	17	9	23	15	14	18	15	-	-	169
	Agreement with actual age	-	-	-	100%	94%	100%	87%	100%	78%	91%	53%	57%	39%	20%	-	-	75%
Reader 2	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Norw HG	Mean age recorded	-	-	-	3.00	4.17	5.05	6.13	7.00	7.90	8.57	9.93	9.64	11.00	11.33	-	-	
	2stdev	-	-	-	0.00	1.03	0.81	1.28	1.41	1.48	2.07	1.92	2.89	1.37	2.69	-	-	
	CV(%)	-	-	-	0%	12%	8%	10%	10%	9%	12%	10%	15%	6%	12%	-	-	10%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	100%	72%	84%	60%	71%	50%	39%	53%	7%	22%	20%	-	-	51%
Reader 3	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain PA	Mean age recorded	-	-	-	3.33	4.00	4.89	5.73	6.65	7.60	8.35	9.33	10.36	11.39	11.87	-	-	
	2stdev	-	-	-	1.03	1.19	0.92	0.92	1.21	1.40	1.43	1.23	1.27	1.40	1.67	-	-	
	CV(%)	-	-	-	15%	15%	9%	8%	9%	9%	9%	7%	6%	6%	7%	-	-	9%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	67%	67%	79%	73%	53%	40%	35%	40%	21%	33%	27%	-	-	48%
Reader 4	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain OP	Mean age recorded	-	-	-	2.83	4.22	5.00	5.93	6.88	7.70	8.57	9.40	9.29	10.72	10.53	-	-	
	2stdev	-	-	-	0.82	1.10	2.00	1.77	1.71	1.65	2.40	2.81	2.65	3.05	2.12	-	-	
	CV(%)	-	-	-	14%	13%	20%	15%	12%	11%	14%	15%	14%	14%	10%	-	-	14%
	Number of age readings	-	-	-	6	18	18	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	83%	67%	47%	27%	65%	30%	30%	20%	7%	6%	0%	-	-	33%
Reader 5	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain IR	Mean age recorded	-	-	-	3.00	4.06	4.89	5.80	6.71	7.90	8.39	9.40	9.14	10.44	11.13	-	-	
	2stdev	-	-	-	0.00	1.45	0.92	1.72	1.18	1.14	1.57	2.37	2.81	1.97	2.25	-	-	
	CV(%)	-	-	-	0%	18%	9%	15%	9%	7%	9%	13%	15%	9%	10%	-	-	11%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	100%	50%	79%	47%	59%	70%	43%	7%	14%	11%	7%	-	-	41%
Reader 6	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Port LS	Mean age recorded	-	-	-	3.00	4.17	5.53	6.27	7.71	8.10	8.39	9.47	9.43	10.78	10.87	-	-	
	2stdev	-	-	-	0.00	1.03	1.93	1.60	2.53	1.99	2.39	2.91	3.30	3.26	1.80	-	-	
	CV(%)	-	-	-	0%	12%	17%	13%	16%	12%	14%	15%	18%	15%	8%	-	-	14%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	100%	72%	47%	53%	47%	40%	26%	33%	29%	33%	0%	-	-	41%
Reader 7	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Port AMC	Mean age recorded	-	-	-	3.33	4.72	6.16	6.67	7.35	8.30	8.96	9.87	9.79	10.56	10.67	-	-	
	2stdev	-	-	-	1.03	2.04	1.92	1.80	1.72	0.97	1.65	1.83	2.38	1.97	2.58	-	-	
	CV(%)	-	-	-	15%	22%	16%	13%	12%	6%	9%	9%	12%	9%	12%	-	-	12%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	67%	33%	26%	53%	53%	70%	48%	40%	29%	17%	13%	-	-	38%
Reader 8	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Irel LB	Mean age recorded	-	-	-	3.00	4.28	5.37	6.60	7.18	8.20	8.83	10.27	10.07	11.06	10.80	-	-	
	2stdev	-	-	-	0.00	1.34	2.33	2.11	2.03	2.27	2.31	3.16	2.77	3.25	3.04	-	-	
	CV(%)	-	-	-	0%	16%	22%	16%	14%	14%	13%	15%	14%	15%	14%	-	-	15%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	100%	67%	58%	33%	53%	40%	17%	27%	43%	17%	13%	-	-	39%
Reader 9	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Irel EM	Mean age recorded	-	-	-	3.00	4.22	5.11	6.47	7.59	8.60	9.22	9.67	10.21	11.17	11.53	-	-	
	2stdev	-	-	-	1.26	1.76	1.62	3.01	2.56	2.70	2.56	2.58	1.95	2.40	1.49	-	-	
	CV(%)	-	-	-	21%	21%	16%	23%	17%	16%	14%	13%	10%	11%	6%	-	-	15%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	67%	56%	79%	40%	29%	50%	48%	13%	36%	44%	7%	-	-	42%
Reader 10	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Neth SR	Mean age recorded	-	-	-	2.33	3.72	5.74	6.93	9.00	8.80	9.17	9.80	9.86	11.11	11.60	-	-	
	2stdev	-	-	-	1.03	2.36	2.57	3.07	3.32	2.27	3.28	3.31	2.81	3.49	3.19	-	-	
	CV(%)	-	-	-	22%	32%	22%	22%	18%	13%	18%	17%	14%	16%	14%	-	-	19%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	33%	22%	32%	20%	6%	10%	17%	13%	29%	50%	20%	-	-	23%
Reader 11	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Neth BC	Mean age recorded	-	-	-	3.00	4.56	5.79	6.33	7.29	7.80	8.70	8.87	10.36	10.94	11.40	-	-	
	2stdev	-	-	-	0.00	1.97	1.84	1.63	1.18	0.84	2.44	2.37	2.02	3.10	1.82	-	-	
	CV(%)	-	-	-	0%	22%	16%	13%	8%	5%	14%	13%	10%	14%	8%	-	-	12%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	100%	39%	32%	47%	59%	80%	35%	33%	29%	17%	7%	-	-	38%
Reader 12	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Germ AC	Mean age recorded	-	-	-	2.83	4.22	5.32	6.20	7.29	7.80	8.30	9.20	9.79	10.39	11.60	-	-	
	2stdev	-	-	-	0.82	1.29	1.16	0.83	1.18	1.26	2.13	1.55	2.74	2.29	2.81	-	-	
	CV(%)	-	-	-	14%	15%	11%	7%	8%	8%	13%	8%	14%	11%	12%	-	-	11%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	83%	56%	74%	80%	59%	60%	30%	40%	21%	11%	13%	-	-	45%
Reader 13	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Germ GG	Mean age recorded	-	-	-	2.67	4.67	6.00	7.93	8.88	9.30	9.61	10.07	10.21	11.44	10.87	-	-	
	2stdev	-	-	-	1.03	2.17	2.58	2.33	2.44	1.65	2.68	2.33	2.38	2.93	2.60	-	-	
	CV(%)	-	-	-	19%	23%	22%	15%	14%	9%	14%	12%	12%	13%	12%	-	-	15%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	67%	22%	42%	20%	6%	10%	39%	33%	7%	50%	0%	-	-	26%
Reader 14	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Denm AT	Mean age recorded	-	-	-	2.67	3.78	4.84	6.00	7.76	7.90	8.96	9.53	9.71	11.39	10.93	-	-	
	2stdev	-	-	-	1.03	1.10	1.80	1.51	2.50	2.74	3.04	2.49	3.18	3.00	3.16	-	-	
	CV(%)	-	-	-	19%	15%	19%	13%	16%	17%	17%	13%	16%	13%	14%	-	-	16%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	67%	67%	37%	47%	12%	40%	35%	40%	14%	28%	20%	-	-	35%
Reader 15	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Eng PW	Mean age recorded	-	-	-	3.33	4.00	5.26	6.53	7.24	7.70	8.13	9.40	9.50	10.39	10.73	-	-	
	2stdev	-	-	-	1.63	0.69	1.12	1.67	0.87	0.97	2.97	2.11	1.71	1.40	2.67	-	-	
	CV(%)	-	-	-	24%	9%	11%	13%	6%	6%	18%	11%	9%	7%	12%	-	-	11%
	Number of age readings	-	-	-	6	18	19	15	17	10	23	15	14	18	15	-	-	170
	Agreement with actual age	-	-	-	83%	89%	63%	67%	76%	70%	48%	40%	14%	0%	0%	-	-	44%
ALL READERS	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
	Mean age recorded	-	-	-	2.96	4.19	5.33	6.37	7.44	8.08	8.74	9.59	9.84	10.93	11.14	-	-	
	2stdev	-	-	-	0.94	1.56	1.87	2.09	2.29	1.95	2.42	2.39	2.57	2.64	2.56	-	-	
	CV(%)	-	-	-	16%	19%	17%	16%	15%	12%	14%	12%	13%	12%	11%	-	-	15%
	Number of age readings	-	-	-	90	270	285	225	255	149	345	225	210	270	225	-	-	2549
	Agreement with actual age	-	-	-	81%	58%	59%	50%	50%	49%	39%	32%	24%	25%	11%	-	-	42%

Table 5.3 Horse Mackerel Otolith SET I (WKHMO, Lowestoft, 15-19 January 1999)

Otol. no	RIVO Sample	Fish no	Fish length	Landing month	S.Afr MK Reader 1	Norw HG Reader 2	Spain PA Reader 3	Spain OP Reader 4	Spain IR Reader 5	Port LS Reader 6	Port AMC Reader 7	Irel LB Reader 8	Irel EM Reader 9	Neth SR Reader 10	Neth BC Reader 11	Germ AC Reader 12	Germ GG Reader 13	Denm AT Reader 14	Eng PW Reader 15	ACTUAL AGE	Age difference	Average
1	-	2	15.2	9	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1.07
2	-	27	15.8	10	2	1	1	2	2	1	2	2	2	2	2	2	2	1	1	1	1	1.67
3	-	4	17.7	10	2	1	1	1	2	1	1	1	2	3	1	2	2	1	1	1	2	1.47
4	-	31	18.4	10	4	2	3	2	3	2	2	3	4	3	3	3	4	2	3	3	2	2.87
5	-	8	18.8	10	2	1	2	2	2	2	1	2	2	4	1	2	2	1	2	1	3	1.87
6	-	13	19.1	10	2	1	1	2	2	1	1	1	2	2	2	2	2	1	2	1	1	1.60
8	-	26	19.6	10	3	2	3	3	3	2	2	3	3	3	2	3	3	2	2	2	1	2.60
10	-	5	19.9	10	4	2	4	2	4	2	2	3	3	3	2	3	3	1	2	3	3	2.67
12	-	40	20.3	10	3	2	3	3	4	2	3	3	3	2	4	3	3	3	4	3	2	3.00
14	-	21	20.4	10	3	2	3	4	4	2	3	3	3	3	4	3	3	3	3	3	2	3.07
16	-	32	20.6	10	3	2	2	3	3	2	2	3	3	3	2	3	3	2	2	2	1	2.53
18	-	24	21.0	10	4	3	3	3	4	3	3	3	3	3	3	3	4	3	3	3	1	3.20
20	-	40	21.1	10	3	2	3	3	3	2	3	3	3	3	2	2	3	2	2	2	1	2.60
22	-	45	21.7	10	4	3	4	4	5	3	3	3	3	3	4	4	3	3	3	3	2	3.47
24	-	50	21.9	10	3	3	3	4	3	3	2	2	3	3	3	3	3	2	3	3	2	2.87
26	-	18	22.2	10	3	3	2	3	3	2	2	2	3	3	3	3	3	2	2	2	1	2.60
27	-	17	22.3	9	4	3	4	5	4	-	3	3	5	4	4	4	3	3	8	4	5	4.07
28	-	46	22.5	10	3	2	3	3	3	2	2	2	3	3	2	3	2	2	2	2	1	2.47
30	-	6	23.4	10	5	4	4	5	5	3	3	2	5	5	4	5	5	3	4	4	3	4 13
32	-	4	23.7	11	6	4	5	9	6	5	4	7	6	5	9	6	5	6	4	6	5	5.80
33	-	7	24.2	9	6	6	5	7	7	6	6	5	7	5	7	6	6	6	6	6	2	6.07
34	-	8	24.3	10	9	8	9	9	12	7	7	9	9	7	8	9	7	6	7	9	6	8.20
36	-	11	24.4	10	9	7	7	9	8	7	7	8	9	7	8	8	7	6	8	9	3	7.53
38	-	12	24.7	10	4	4	4	6	5	5	4	5	5	4	7	5	5	4	4	4	3	4.73
40	-	3	24.7	9	7	5	7	8	9	7	6	8	7	6	7	7	7	5	7	7	4	6.80
42	-	2	24.7	10	10	7	10	9	10	6	9	9	9	9	11	9	7	8	12	11	6	9.00
44	-	5	24.8	9	5	5	4	5	6	5	8	4	5	5	4	5	5	5	5	5	2	4.87
46	-	1	25.0	11	11	10	11	11	9	10	6	8	11	12	9	11	6	8	12	11	6	9 73
48	-	3	25.2	9	10	10	10	13	12	8	11	10	10	9	9	10	7	11	9	10	6	9 93
50	-	14	25.3	9	9	7	6	7	9	6	7	7	7	5	7	7	7	8	7	7	4	7 07
52	-	10	25.4	11	10	9	8	12	9	7	5	8	10	7	10	8	8	8	9	9	7	8.53
54	-	5	25.5	9	5	4	5	7	7	6	4	5	5	6	6	6	7	7	6	5	3	5.73
56	-	7	25.6	9	8	8	8	11	8	6	5	5	8	7	10	7	7	7	7	8	6	7.47
58	-	15	25.7	10	8	7	7	10	8	7	5	5	8	7	9	7	7	9	7	8	5	7 40
60	-	14	25.7	9	6	8	8	13	7	6	5	8	8	6	7	6	6	9	6	6	8	6.87
62	-	2	25.8	9	12	12	12	13	12	10	11	11	13	8	12	12	12	10	12	12	5	11 47
64	-	13	25.9	9	5	4	5	6	5	4	4	4	5	5	4	5	5	6	5	5	2	4 80
65	-	20	26.0	9	6	8	8	8	6	5	5	5	6	6	5	6	5	5	7	6	3	5.80
66	-	16	26.1	10	4	5	6	8	5	7	4	4	6	6	5	5	5	6	5	4	3	5.27
68	-	17	26.1	11	9	9	8	10	8	9	6	8	9	7	7	9	10	9	9	9	4	8.47
70	-	2	26.1	11	8	8	8	9	9	9	7	8	9	7	8	8	9	9	8	9	2	8.27
72	-	21	26.2	9	11	9	10	13	11	11	8	6	10	6	9	7	9	9	10	10	7	9 27
74	-	17	26.3	11	11	9	9	11	10	11	9	8	10	8	10	9	9	9	10	10	5	9.40
76	-	15	26.3	10	11	10	11	11	10	10	10	9	11	9	11	10	11	10	10	11	2	10.27
78	-	20	26.5	9	7	6	7	8	9	9	8	6	9	7	7	7	7	7	8	7	3	7.47
80	-	11	26.6	10	12	8	10	10	11	9	8	8	10	9	10	10	10	8	8	10	4	9.40
82	-	3	26.7	9	13	11	12	13	9	12	10	10	12	13	12	12	9	10	10	12	4	11.20
84	-	7	26.8	10	10	9	9	12	9	9	9	11	13	11	10	10	10	10	10	10	4	10.13
86	-	7	26.8	11	13	11	11	12	12	11	10	11	10	11	10	11	10	8	12	12	5	10 87
88	-	5	26.9	10	5	5	5	6	5	5	4	5	5	5	5	5	6	5	5	5	2	5.07
90	-	19	27.2	10	12	11	11	12	11	11	10	11	11	12	12	12	12	11	11	12	2	11.33
92	-	24	27.3	9	8	7	6	7	9	9	5	6	7	7	8	7	7	6	8	7	4	7 13
94	-	9	27.3	11	7	6	7	8	7	8	7	7	9	7	7	7	7	7	6	8	3	7 13
98	-	19	27.5	10	10	10	10	11	11	11	9	8	11	10	10	10	10	8	12	10	4	10.07
100	-	19	27.5	10	11	11	11	13	12	11	8	9	11	11	13	11	9	8	10	11	7	10.47
104	-	12	27.7	11	3	3	4	7	5	5	4	3	6	8	4	6	5	5	4	4	5	4.80
108	-	7	27.8	9	12	-	11	13	-	10	-	-	11	12	12	12	-	10	12	12	3	11 50
110	-	7	27.9	9	9	7	9	11	9	8	8	8	9	9	8	9	7	7	10	9	4	8.53
112	-	23	28.0	11	13	11	12	13	12	11	11	10	12	12	12	12	8	12	12	12	5	11.53
114	-	18	28.3	9	9	8	9	12	9	10	9	7	8	9	9	9	9	7	8	9	5	8.80
116	-	21	28.3	9	13	12	11	12	12	13	12	10	12	11	12	12	10	10	12	12	3	11 60
118	-	24	28.4	11	9	12	10	12	11	11	9	9	9	11	11	10	10	9	10	10	3	10 20
120	-	19	28.5	11	10	10	12	13	12	11	9	7	11	10	11	11	11	12	10	11	6	10.67
122	-	19	28.7	11	8	8	7	11	9	6	5	6	9	7	7	8	7	6	7	7	6	7 40
124	-	22	28.8	9	8	7	7	10	9	7	6	7	9	7	9	9	8	7	9	8	4	7.93
126	-	19	29.1	11	9	8	7	10	10	7	6	7	9	7	8	9	8	6	8	8	4	7.93
128	-	14	29.3	10	9	8	7	11	9	7	6	7	7	8	9	8	7	8	8	8	5	7.93
130	-	20	30.1	10	5	5	5	10	6	7	4	4	6	7	7	6	5	7	6	5	6	6.00
131	-	22	30.7	11	6	5	6	13	10	8	6	10	12	8	8	8	6	7	7	6	8	8 00
132	-	20	31.0	10	8	8	8	11	10	7	6	7	11	8	8	8	8	8	8	8	5	8 27
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				Total read	70	69	70	70	69	69	69	69	70	70	70	70	69	70	70			
				Total NOT read	0	1	0	0	1	1	1	1	0	0	0	0	1	0	0			

Horse Mackerel Otolith SET I (WKHMO, Lowestoft, 15-19 January 1999)

Table 5.4 The mean age recorded, 2stdev, the number of age readings and the agreement with actual age are presented by actual age for each reader and for all readers combined. The total number of age readings and the weighted means of CV and agreement are given for age groups 0-15. Precision is indicated by CV and accuracy by agreement.

Reader 1	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
S.Afr MK	Mean age recorded	-	1.80	3.00	3.57	4.00	5.00	6.00	7.80	8.13	9.17	10.43	10.60	12.57	-	-	-	
	2stdev	-	0.89	0.00	1.07	1.41	0.00	0.00	1.67	1.28	0.82	1.95	1.10	1.07	-	-	-	
	CV(%)	-	25%	0%	15%	18%	0%	0%	11%	8%	4%	9%	5%	4%	-	-	-	9%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	20%	0%	43%	60%	100%	100%	40%	63%	83%	43%	60%	43%	-	-	-	54%
Reader 2	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Norw HG	Mean age recorded	-	1.00	2.20	2.43	3.80	4.60	5.40	6.60	7.50	8.00	9.57	9.60	11.33	-	-	-	
	2stdev	-	0.00	0.89	1.07	1.67	1.10	1.79	2.28	1.51	1.79	2.54	3.03	1.03	-	-	-	
	CV(%)	-	0%	20%	22%	22%	12%	17%	17%	10%	11%	13%	16%	5%	-	-	-	14%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	6	-	-	-	69
	Agreement with actual age	-	100%	80%	43%	40%	60%	60%	40%	63%	33%	29%	20%	33%	-	-	-	49%
Reader 3	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain PA	Mean age recorded	-	1.20	2.60	3.29	4.40	4.80	5.60	6.60	7.38	8.33	9.71	11.00	11.43	-	-	-	
	2stdev	-	0.89	1.10	0.98	1.79	0.89	1.10	1.10	1.04	1.63	0.98	1.41	1.07	-	-	-	
	CV(%)	-	37%	21%	15%	20%	9%	10%	8%	7%	10%	5%	6%	5%	-	-	-	12%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	80%	40%	71%	80%	80%	60%	60%	38%	50%	71%	60%	43%	-	-	-	60%
Reader 4	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain GP	Mean age recorded	-	1.60	3.00	3.14	5.80	6.80	10.00	8.40	10.00	10.50	11.71	11.40	12.57	-	-	-	
	2stdev	-	1.10	0.00	1.80	1.67	3.85	5.66	3.35	2.14	2.76	2.23	3.35	1.07	-	-	-	
	CV(%)	-	34%	0%	29%	14%	28%	28%	20%	11%	13%	9%	15%	4%	-	-	-	17%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	40%	0%	29%	0%	20%	0%	40%	13%	33%	14%	40%	43%	-	-	-	23%
Reader 5	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain IR	Mean age recorded	-	1.80	3.00	3.86	4.80	5.60	7.20	9.00	8.75	9.17	10.71	10.60	11.33	-	-	-	
	2stdev	-	0.89	0.00	1.38	0.89	1.79	3.29	0.00	2.07	2.94	1.90	2.68	2.42	-	-	-	
	CV(%)	-	25%	0%	18%	9%	16%	23%	0%	12%	16%	9%	13%	11%	-	-	-	13%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	6	-	-	-	69
	Agreement with actual age	-	20%	0%	29%	20%	60%	40%	0%	25%	50%	14%	0%	67%	-	-	-	28%
Reader 6	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Port LS	Mean age recorded	-	1.20	2.00	2.43	5.00	5.40	6.00	7.40	7.25	8.00	10.00	9.60	11.14	-	-	-	
	2stdev	-	0.89	0.00	1.07	3.27	2.28	2.46	3.03	1.77	2.53	2.58	4.15	2.14	-	-	-	
	CV(%)	-	37%	0%	22%	33%	21%	20%	20%	12%	16%	13%	22%	10%	-	-	-	18%
	Number of age readings	-	5	5	7	4	5	5	5	8	6	7	5	7	-	-	-	69
	Agreement with actual age	-	80%	100%	43%	0%	40%	40%	20%	13%	17%	0%	40%	14%	-	-	-	32%
Reader 7	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Port AMC	Mean age recorded	-	1.20	2.20	2.57	3.80	4.40	5.20	6.20	6.00	7.00	9.00	8.00	10.67	-	-	-	
	2stdev	-	0.89	0.89	1.07	1.10	1.79	1.67	2.61	1.51	2.83	2.00	3.74	1.63	-	-	-	
	CV(%)	-	37%	20%	21%	15%	20%	18%	21%	13%	20%	11%	23%	8%	-	-	-	18%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	6	-	-	-	69
	Agreement with actual age	-	80%	80%	57%	60%	0%	40%	20%	0%	17%	0%	0%	17%	-	-	-	29%
Reader 8	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Irel LB	Mean age recorded	-	1.40	2.60	2.86	3.40	4.40	6.60	8.20	6.63	7.67	8.57	8.60	10.50	-	-	-	
	2stdev	-	1.10	1.10	0.76	2.28	1.10	4.15	0.89	2.12	2.07	3.24	1.79	1.10	-	-	-	
	CV(%)	-	39%	21%	13%	34%	12%	31%	7%	16%	13%	19%	10%	5%	-	-	-	18%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	6	-	-	-	69
	Agreement with actual age	-	60%	40%	86%	20%	40%	20%	20%	13%	17%	14%	0%	0%	-	-	-	28%
Reader 9	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Irel EM	Mean age recorded	-	1.80	3.00	3.14	5.40	5.20	7.80	7.80	8.75	9.00	10.43	10.60	11.57	-	-	-	
	2stdev	-	0.89	0.00	0.76	1.10	0.89	4.98	2.19	2.33	1.26	2.54	1.79	1.95	-	-	-	
	CV(%)	-	25%	0%	12%	10%	9%	32%	14%	13%	7%	12%	8%	8%	-	-	-	12%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	20%	0%	86%	0%	80%	40%	60%	25%	67%	57%	80%	43%	-	-	-	47%
Reader 10	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Neth SR	Mean age recorded	-	2.60	3.00	2.86	5.40	5.60	6.00	6.40	7.25	7.67	8.86	10.20	11.29	-	-	-	
	2stdev	-	1.79	0.00	0.76	3.35	1.79	2.45	1.79	0.93	2.07	4.23	2.61	3.21	-	-	-	
	CV(%)	-	34%	0%	13%	31%	16%	20%	14%	6%	13%	24%	13%	14%	-	-	-	16%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	0%	0%	86%	40%	60%	40%	60%	25%	33%	14%	20%	43%	-	-	-	36%
Reader 11	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Neth BC	Mean age recorded	-	1.40	2.20	3.29	4.80	5.20	7.20	7.20	8.50	8.33	9.86	11.00	11.71	-	-	-	
	2stdev	-	1.10	0.89	1.51	2.61	2.61	2.97	0.89	1.85	2.07	1.38	2.83	1.51	-	-	-	
	CV(%)	-	39%	20%	23%	27%	25%	21%	6%	11%	12%	7%	13%	6%	-	-	-	17%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	60%	80%	43%	60%	20%	0%	80%	38%	17%	57%	60%	86%	-	-	-	50%
Reader 12	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Germ AC	Mean age recorded	-	1.80	2.80	3.14	5.00	5.40	6.40	7.20	7.88	8.67	9.43	10.40	11.86	-	-	-	
	2stdev	-	0.89	0.89	0.76	1.41	1.10	1.79	0.89	1.67	1.03	2.27	1.79	0.76	-	-	-	
	CV(%)	-	25%	16%	12%	14%	10%	14%	6%	11%	6%	12%	9%	3%	-	-	-	11%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	20%	20%	86%	20%	60%	80%	80%	38%	67%	71%	60%	86%	-	-	-	59%
Reader 13	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Germ GG	Mean age recorded	-	1.80	2.80	3.29	4.60	5.60	5.60	7.00	7.63	8.00	9.29	8.80	10.17	-	-	-	
	2stdev	-	0.89	0.89	0.98	1.79	1.79	1.10	0.00	1.49	2.53	2.23	4.56	3.20	-	-	-	
	CV(%)	-	25%	16%	15%	19%	16%	10%	0%	10%	16%	12%	26%	16%	-	-	-	15%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	6	-	-	-	69
	Agreement with actual age	-	20%	20%	71%	0%	60%	60%	100%	38%	17%	57%	40%	33%	-	-	-	43%
Reader 14	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Denm AT	Mean age recorded	-	1.00	2.00	2.43	4.20	6.00	6.60	6.40	7.63	7.17	9.14	9.20	10.14	-	-	-	
	2stdev	-	0.00	0.00	1.57	2.61	2.00	3.03	2.28	2.12	2.34	2.14	3.58	2.43	-	-	-	
	CV(%)	-	0%	0%	32%	31%	17%	23%	18%	14%	18%	12%	19%	12%	-	-	-	16%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	100%	100%	57%	20%	40%	40%	20%	25%	17%	14%	0%	14%	-	-	-	36%
Reader 15	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Eng PW	Mean age recorded	-	1.40	2.00	3.00	5.00	5.40	6.00	7.40	7.63	8.50	9.86	10.80	11.57	-	-	-	
	2stdev	-	1.10	0.00	1.15	3.46	1.10	2.45	1.10	1.83	2.10	2.43	2.19	1.57	-	-	-	
	CV(%)	-	39%	0%	19%	35%	10%	20%	7%	12%	12%	12%	10%	7%	-	-	-	15%
	Number of age readings	-	5	5	7	5	5	5	5	8	6	7	5	7	-	-	-	70
	Agreement with actual age	-	60%	100%	71%	60%	60%	40%	60%	50%	33%	57%	0%	71%	-	-	-	56%
ALL READERS	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
	Mean age recorded	-	1.53	2.56	3.02	4.61	5.29	6.51	7.17	7.79	8.34	9.77	10.03	11.35	-	-	-	
	2stdev	-	1.20	1.00	1.36	2.38	2.05	3.56	2.33	2.49	2.62	2.75	3.25	2.26	-	-	-	
	CV(%)	-	39%	20%	22%	26%	19%	27%	16%	16%	15%	14%	16%	10%	-	-	-	20%
	Number of age readings	-	75	75	105	74	75	75	75	120	90	105	75	100	-	-	-	1044
	Agreement with actual age	-	51%	44%	60%	32%	52%	44%	47%	31%	37%	34%	32%	43%	-	-	-	42%

Table 6.1 Horse Mackerel Otolith SET K (WKHMO, Lowestoft, 15-19 January 1999)

Otol. no	RIVO Sample	Fish no	Fish length	Landing month	S.Afr MK Reader 1	Norw HG Reader 2	Spain PA Reader 3	Spain CP Reader 4	Spain IR Reader 5	Port LS Reader 6	Port AMC Reader 7	Irel LB Reader 8	Irel EM Reader 9	Neth SR Reader 10	Neth BC Reader 11	Germ AC Reader 12	Germ GG Reader 13	Denm AT Reader 14	Eng PW Reader 15	ACTUAL AGE	Age difference	Average
1	21	2	14.2	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1.00
2	19	1	14.9	9	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1.07
3	21	10	18.9	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1.00
4	46	27	19.4	10	1	2	3	2	2	2	2	2	3	2	3	2	3	2	3	3	2	2.27
5	45	14	19.8	10	2	2	3	2	2	1	2	3	3	3	2	2	3	1	2	3	2	2.20
6	46	37	20.3	10	3	2	3	3	3	2	2	2	3	2	2	3	3	1	2	3	2	2.40
7	30	30	20.4	10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	0	2.00
8	22	2	20.6	9	4	3	4	4	3	3	3	3	4	3	3	3	4	3	3	4	1	3.33
9	5	5	20.8	4	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	3	1	3.07
10	5	6	20.9	4	3	3	3	3	4	3	3	3	3	3	3	3	3	3	3	3	1	3.07
11	50	48	21.2	10	3	3	3	3	4	3	2	3	3	3	3	3	3	3	3	3	2	3.00
12	28	30	21.4	10	2	2	2	2	3	2	2	2	3	4	2	2	3	2	2	2	2	2.33
13	10	1	21.7	4	4	4	5	4	4	4	3	3	4	4	3	4	4	4	4	4	2	3.87
14	21	10	21.7	9	4	4	4	4	5	3	3	4	4	4	4	5	4	3	4	4	2	3.93
15	27	6	21.8	10	2	2	2	2	3	2	2	3	2	2	2	2	2	2	2	2	1	2.13
16	27	14	22.0	10	2	2	2	3	3	2	2	2	3	3	2	2	2	2	2	2	1	2.27
17	3	42	22.3	3	3	3	3	2	3	3	3	4	3	4	6	2	4	3	3	3	4	3 27
18	3	43	22.4	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	1	3.07
19	30	43	22.9	10	2	2	3	4	3	2	2	2	3	4	2	3	3	2	2	2	2	2.60
20	3	15	23.1	3	3	3	3	3	3	3	3	3	3	4	3	3	4	3	3	3	1	3 13
21	7	5	23.2	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	4	1	4.07
22	11	4	23.3	4	4	4	5	4	4	4	4	3	4	5	4	4	4	3	5	4	2	4 07
23	32	8	23.3	10	4	4	4	4	5	3	3	4	4	4	4	5	3	3	4	4	2	3.87
24	21	21	23.4	9	4	3	4	3	4	3	4	3	4	4	4	4	4	2	3	4	2	3 53
25	10	3	23.5	4	4	4	4	5	5	4	4	4	5	5	5	5	5	3	5	4	2	4.47
26	1	5	23.7	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	4 00
27	7	2	23.8	4	4	4	4	4	4	4	3	4	4	4	3	4	4	4	4	4	1	3.87
28	4	7	24.0	2	4	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	1	4.07
29	48	2	24.1	9	5	5	6	5	6	5	5	5	6	5	4	6	5	5	5	7	2	5.20
30	2	2	24.3	3	5	5	6	5	5	5	5	5	5	5	5	5	5	4	5	5	2	5.00
31	33	9	24.3	9	5	5	6	6	5	5	8	5	7	5	6	5	5	5	6	6	2	5.47
32	1	8	24.5	2	4	4	4	4	5	4	5	4	4	4	4	4	3	4	4	4	2	4.07
33	7	7	24.5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	4	1	3.93
34	44	4	24.6	9	6	6	6	8	7	5	10	6	7	6	6	5	6	6	7	7	5	6 47
35	64	4	24.6	10	9	8	9	8	8	7	10	8	8	8	9	8	8	8	8	9	3	8.27
36	14	14	24.7	5	4	4	4	4	4	4	7	5	4	4	4	4	4	5	4	4	3	4 33
37	44	11	24.8	9	7	6	6	6	6	6	9	8	7	6	6	6	6	6	5	7	4	6 27
38	49	2	24.8	11	5	5	5	6	5	5	10	5	6	5	5	5	5	6	5	6	5	5.53
39	75	5	25.0	11	9	8	8	9	8	6	10	8	9	7	8	8	8	8	8	9	4	8 13
40	7	1	25.1	3	8	9	8	8	8	7	9	8	8	8	7	8	8	8	8	8	2	8.00
41	7	6	25.1	3	5	5	5	4	5	5	5	5	5	5	5	5	6	5	5	5	2	5.00
42	41	9	25.1	9	12	9	11	12	8	9	12	9	10	9	11	9	9	8	6	10	6	9.60
43	7	16	25.3	4	3	4	4	4	4	4	5	4	4	5	4	4	5	6	4	4	3	4 27
44	55	19	25.3	10	7	7	7	6	8	7	7	7	9	7	7	7	8	8	8	8	3	7 33
45	7	7	25.4	3	5	5	5	6	6	5	6	5	5	5	3	5	6	6	5	5	3	5.20
46	32	21	25.4	10	4	4	4	4	6	4	5	5	4	4	4	4	5	4	4	4	1	4.27
47	33	9	25.4	9	4	4	4	4	5	4	5	4	5	4	4	5	5	5	5	5	1	4.47
48	6	1	25.5	3	7	7	8	6	7	7	9	6	7	7	8	7	7	10	8	7	4	7.40
49	48	12	25.6	9	6	7	7	6	7	6	9	6	7	8	6	7	7	8	6	7	3	6.87
50	33	15	25.6	9	5	5	5	6	6	5	8	6	6	5	5	6	6	7	6	6	3	5.80
51	8	3	25.7	2	6	6	7	5	6	6	6	7	6	6	7	6	6	6	6	6	2	6 07
52	9	5	25.7	4	4	4	4	4	5	4	4	4	4	4	5	4	4	4	4	4	1	4.13
53	46	8	25.7	9	8	6	7	7	7	5	6	6	7	7	8	7	7	7	7	8	3	6.67
54	5	6	25.8	2	6	6	7	6	6	6	6	6	6	6	6	6	7	6	6	6	1	6.13
55	6	10	25.8	3	5	5	5	6	5	5	8	5	5	6	5	6	6	6	5	5	1	5.40
56	49	7	25.8	11	6	5	6	5	7	4	6	6	6	6	7	6	7	6	5	6	3	5.87
57	1	17	25.9	2	4	4	4	4	4	4	5	4	4	4	4	4	6	4	4	4	2	4.20
58	64	10	25.9	10	9	9	9	8	9	8	10	9	10	8	8	9	11	9	8	9	3	8 93
59	6	16	26.0	3	6	5	5	5	5	5	11	6	7	5	5	5	5	5	5	5	6	5.60
60	94	12	26.0	10	11	8	8	9	8	6	12	9	10	8	8	8	10	11	8	11	6	8.93
61	33	17	26.2	9	5	5	5	5	5	5	5	6	6	11	5	5	5	6	5	5	6	5 60
62	75	21	26.3	11	9	8	8	7	9	9	10	8	9	9	10	9	9	9	8	9	3	8 73
63	101	11	26.3	11	12	10	10	11	10	10	12	10	11	9	10	8	13	10	10	11	5	10.40
64	4	12	26.4	3	5	5	5	5	5	5	7	5	5	4	5	5	5	6	5	5	3	5 13
65	12	2	26.4	5	4	5	5	4	5	5	8	4	5	5	4	4	5	6	5	4	4	4 93
66	41	16	26.4	9	9	9	9	8	9	9	11	8	9	10	8	10	11	9	8	10	3	9 13
67	94	9	26.5	10	11	8	10	9	10	9	12	9	11	9	10	9	11	11	10	11	4	9.93
68	48	15	26.6	10	10	9	9	10	9	8	12	8	9	8	8	9	7	8	8	10	5	8 80
69	93	10	26.6	10	12	10	11	8	10	11	11	10	11	10	11	11	11	12	11	12	4	10 67
70	4	11	26.7	2	6	5	6	5	6	6	6	7	6	6	5	6	6	6	6	6	2	5.87
71	3	7	26.7	2	6	6	6	6	6	5	6	6	8	6	6	6	8	7	6	6	3	6 27
72	7	2	26.7	3	8	8	8	8	10	9	10	7	8	9	8	9	10	10	8	9	3	8 67
73	2	4	26.8	2	7	8	8	8	8	8	9	6	8	8	8	8	9	10	7	9	4	7.87
74	48	4	26.8	10	10	9	10	8	10	9	11	9	10	9	8	10	12	9	9	10	4	9.53
75	33	22	26.8	9	5	6	5	5	6	5	6	5	6	5	6	5	7	7	5	6	2	5 60
76	5	2	26.9	2	10	10	10	9	10	9	11	10	10	10	10	10	10	12	10	10	3	10.07
77	1	14	26.9	2	6	6	7	8	7	8	8	6	6	6	6	6	8	7	7	6	2	6 80
78	2	7	26.9	2	6	6	6	6	6	7	8	6	6	7	6	7	7	6	6	6	2	6 40
79	57	10	26.9	11	10	10	8	8	7	7	10	10	10	10	9	10	11	8	8	10	4	9 07
80	83	22	27.0	9	11	11	10	10	10	10	11	9	11	11	11	11	12	11	10	11	3	10.60
81	4	5	27.1	1	11	10	10	8	10	10	10	9	12	8	10	8	11	11	9	11	4	9.80
82	94	17	27.1	10	11	12	10	10	11	11	12	11	12	11	11	11	12	12	11	11	2	11.20
83	5	7	27.2	3	8	7	7	7	8	7	9	5	8	7	7	7	7	9	9	8	4	7.47
84	110	12	27.2	11	12	12	12	11	10	8	12	11	11	10	12	10	10	12	9	12	4	10 80
85	6	15	27.3	2	6	5	7	6	6	6	8	6	6	6	6	6	7	7	6	6	3	6.27
86	7	5	27.3	3	9	8	8	8	8	8	9	8	9	9	9	9	8	9	9	9	1	8.60
87	62	8	27.3	11	8	7	8	7	7	6	8	9	7	8	8	8	7	9	8	7	3	7 67
88	1	1	27.4	1	10	12	10	11	10	10	10	8	11	10	11	10	10	11	11	11	4	10 33
89	54	13	27.5	9	7	-	10	-	-	6	9	8	10	7	7	7	12	10	-	9	6	8.45
90	85	18	27.5	9	10	11	10	12	10	9	11	9	10	10	10	10	10	11	11	11	3	10.27
91	5	11	27.6	3	5	5	5	5	5	5	7	4	5	5	5	5	5	6	5	5	3	5 13
92	31	21	27.6	9	5	4	5	5	5	4	8	4	5	5	5	5	4	5	5	5	4	4.93
93	2	8	27.7	2	9	9	9	7	8	8	9	8	8	8	9	8	9	8	8	9	2	8.33
94	57	23	27.7	11	10	11	9	9	10	7	12	7	9	9	11	10	9	11	9	10	5	9.53
95	49	13	27.7	11	6	5	6	6	6	6	10	7	7	5	5	6	6	7	5	6	5	6.20
96	9	2	27.8	1	13	13	12	11	11	12	13	11	12	12	12	13	13	12	11	13	2	12.07
97	2	4	27.8	2	8	8	8	8	8	8	11	8	8	8	8	8	8	9	8	8	3	8 27
98	83	6	27.8	11	8	8	8	8	8	8	9	8	8	8	8	9	8	9	8	8	1	8 20
99	78	6	27.8	9	11	9	11	7	9	9	12	9	11	7	10	11	12	11	10	12	5	9 93
100	49	17	27.9	11	6	6	6	7	6	6	10	7	7	7	8	7	8	9	6	6	4	7.07

101	2	4	28.0	2	9	9	9	9	9	9	11	8	10	8	10	9	11	11	10	10	3	9.47
102	8	20	28.1	2	6	5	6	6	6	7	9	6	8	8	6	6	7	7	6	6	4	6.47
103	110	22	28.1	11	12	12	12	12	11	12	10	10	12	12	13	11	11	12	11	12	3	11.53
104	9	11	28.2	1	12	12	12	9	13	9	13	11	12	12	11	12	15	10	10	13	6	11.53
105	79	23	28.2	9	12	11	9	11	9	10	10	7	11	11	12	9	8	12	12	12	5	10.27
106	3	6	28.4	1	12	12	12	12	11	11	12	11	12	10	12	13	9	13	12	13	4	11.60
107	5	14	28.5	3	8	8	8	7	8	7	9	7	7	7	7	8	8	9	8	8	2	7.73
108	1	3	28.7	2	5	5	5	5	5	6	7	6	5	6	5	5	6	7	5	5	2	5.53
109	6	3	28.7	3	9	9	9	8	9	8	10	8	8	9	8	9	10	9	9	9	2	8.80
110	79	20	28.7	9	10	10	11	10	9	11	11	10	12	9	12	12	13	13	11	12	4	10.93
111	8	23	28.8	3	11	10	11	9	10	10	11	7	11	13	10	10	12	12	11	10	6	10.53
112	62	17	28.8	11	7	8	7	6	7	7	7	7	7	7	8	7	9	7	6	7	3	7.13
113	3	13	29.0	2	9	9	9	8	9	8	10	8	9	9	10	9	10	8	8	9	2	8.87
114	9	17	29.1	1	13	13	12	12	13	11	14	11	13	13	12	13	8	13	13	13	6	12.27
115	43	17	29.1	10	5	5	5	5	5	5	7	6	6	5	5	5	7	8	5	5	2	5.47
116	1	17	29.2	1	13	14	12	12	13	10	14	10	14	12	13	13	16	13	13	13	6	12.80
117	43	23	29.2	10	5	6	5	4	5	5	6	5	6	5	5	5	5	9	5	5	5	5.33
118	2	11	29.3	1	13	14	11	9	12	12	14	10	12	12	11	11	12	13	13	13	5	11.93
119	1	14	29.3	2	7	7	6	5	6	7	7	6	6	7	6	6	8	8	7	7	3	6.60
120	8	11	29.3	3	7	8	7	7	6	7	9	6	7	7	7	7	10	8	7	7	4	7.20
121	49	21	29.3	11	6	5	7	6	6	6	7	5	7	6	5	5	6	8	5	6	3	6.00
122	3	3	29.5	2	8	6	7	5	7	8	9	7	6	9	7	7	9	11	9	7	6	7.67
123	78	23	29.6	9	13	12	12	9	11	11	11	10	11	11	11	11	12	12	12	12	4	11.27
124	6	6	29.7	1	14	13	13	10	9	12	13	10	12	11	13	12	13	11	13	13	5	11.93
125	17	24	29.8	3	12	10	11	11	10	10	10	9	11	10	10	10	12	11	11	11	3	10.53
126	54	21	29.8	9	9	9	9	10	9	9	9	9	11	11	8	7	9	9	9	9	4	9.13
127	4	9	30.0	1	12	11	12	10	12	12	13	10	11	12	10	11	13	11	10	13	3	11.33
128	60	17	30.2	10	8	8	8	8	8	9	8	7	9	8	7	8	10	9	8	8	4	8.07
129	3	7	30.3	1	11	11	10	8	10	10	10	9	9	10	10	10	10	11	9	11	3	9.87
130	3	9	30.5	1	13	11	10	8	9	11	11	9	10	11	9	9	11	10	10	11	5	10.13
131	3	7	30.6	2	7	8	8	7	7	8	9	7	8	8	8	8	9	7	7	7	2	7.73
132	1	17	30.8	1	10	10	11	11	10	10	13	11	12	13	10	10	13	13	10	12	3	11.13
133	7	19	31.0	3	8	8	8	7	8	8	10	7	8	8	8	8	8	10	8	8	3	8.13
134	2	18	31.1	1	11	7	11	10	11	11	13	11	12	13	12	11	12	12	12	12	6	11.27
135	2	7	31.3	2	7	7	7	7	7	7	8	7	7	8	7	7	9	8	7	7	2	7.33
136	49	23	31.3	11	6	5	6	6	6	5	8	6	7	8	6	6	8	7	6	6	3	6.40
137	6	17	31.7	1	13	13	12	11	12	13	13	10	13	12	12	11	13	11	12	13	3	12.07
138	3	24	31.8	2	10	11	10	9	9	11	13	10	11	11	9	10	12	12	10	10	4	10.53
139	4	6	32.2	1	13	12	11	10	10	10	13	11	12	12	11	10	12	12	11	12	3	11.33
140	3	24	32.2	2	8	11	8	9	8	11	10	8	10	8	8	9	10	9	9	8	3	9.07
141	2	11	32.2	2	7	7	7	8	6	7	8	7	7	7	7	7	6	8	7	7	2	6.93
142	8	9	32.3	1	12	12	11	9	11	11	10	9	11	12	11	10	10	11	9	12	3	10.60
143	5	23	32.4	2	9	10	9	9	9	10	12	8	8	9	10	8	8	10	10	10	4	9.33
144	3	12	32.5	1	11	11	12	9	10	11	13	9	10	10	12	10	12	10	11	11	4	10.73
145	1	13	32.6	2	10	10	10	11	11	12	12	8	9	11	10	12	11	11	12	10	4	10.67
146	2	23	32.9	1	11	13	11	13	11	11	12	10	11	11	11	11	11	12	11	12	3	11.33
147	7	24	33.0	1	14	12	12	11	10	13	13	11	12	13	15	13	11	11	13	13	5	12.27
148	6	21	33.4	1	13	13	12	10	11	12	13	10	12	12	11	12	12	13	13	13	3	11.93
149	8	11	33.7	1	12	12	11	12	12	11	11	11	11	12	12	10	11	12	12	12	2	11.47
150	5	22	34.0	1	12	12	12	10	12	10	12	10	11	12	11	11	12	12	12	12	2	11.40
151	5	23	34.4	1	11	13	11	13	11	13	13	13	11	10	12	12	12	13	14	11	4	12.13
152	60	25	34.7	10	8	12	10	12	10	11	10	11	12	10	12	9	10	11	10	8	4	10.53
153	5	24	35.1	1	11	12	11	11	11	12	11	10	12	11	11	11	11	11	10	12	2	11.07
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				Total read	153	152	153	152	152	153	153	153	153	153	153	153	153	153	152			
				Total NOT read	0	1	0	1	1	0	0	0	0	0	0	0	0	0	1			
				Empty rows	47	47	47	47	47	47	47	47	47	47	47	47	47	47	47			

Horse Mackerel Otolith SET K (WKHMO, Lowestoft, 15-19 January 1999)

Table 6.2 The mean age recorded, 2stdev, the number of age readings and the agreement with actual age are presented by actual age for each reader and for all readers combined. The total number of age readings and the weighted means of CV and agreement are given for age groups 0-15. Precision is indicated by CV and accuracy by agreement.

Reader 1	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
S.Afr MK	Mean age recorded	-	1.00	2.00	2.67	3.95	4.92	5.76	6.85	7.91	8.58	10.00	11.15	11.60	12.91	-	-	
	2stdev	-	0.00	0.00	1.41	0.46	0.55	0.87	1.60	0.60	1.59	1.71	1.60	1.82	1.40	-	-	
	CV(%)	-	0%	0%	27%	6%	6%	8%	12%	4%	9%	9%	7%	8%	5%	-	-	8%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	100%	78%	95%	92%	76%	62%	91%	75%	58%	62%	47%	55%	-	-	74%
Reader 2	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Norw HG	Mean age recorded	-	1.00	2.00	2.67	3.95	4.92	5.41	6.69	8.18	8.45	9.75	10.62	11.07	12.73	-	-	
	2stdev	-	0.00	0.00	1.00	0.81	0.99	1.01	1.71	3.78	1.04	1.51	2.89	3.16	1.81	-	-	
	CV(%)	-	0%	0%	19%	10%	10%	9%	13%	23%	6%	8%	14%	14%	7%	-	-	11%
	Number of age readings	-	3	5	9	19	13	17	13	11	11	12	13	15	11	-	-	152
	Agreement with actual age	-	100%	100%	67%	84%	77%	41%	46%	36%	45%	42%	38%	53%	45%	-	-	56%
Reader 3	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain PA	Mean age recorded	-	1.00	2.20	3.00	4.21	5.00	6.12	6.92	7.91	8.67	9.58	10.15	11.13	12.00	-	-	
	2stdev	-	0.00	0.89	0.00	0.84	0.82	1.39	1.52	1.66	1.30	1.80	1.80	1.49	0.89	-	-	
	CV(%)	-	0%	20%	0%	10%	8%	11%	11%	11%	8%	9%	9%	7%	4%	-	-	9%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	80%	100%	79%	85%	53%	46%	64%	50%	33%	15%	27%	9%	-	-	63%
Reader 4	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain QP	Mean age recorded	-	1.00	2.80	2.78	4.00	4.92	5.94	6.38	7.91	8.09	9.25	9.92	10.27	10.64	-	-	
	2stdev	-	0.00	1.79	1.33	0.67	1.28	1.50	2.09	3.16	1.66	2.43	3.21	3.16	2.24	-	-	
	CV(%)	-	0%	34%	24%	8%	13%	13%	16%	20%	10%	13%	16%	15%	11%	-	-	14%
	Number of age readings	-	3	5	9	19	13	17	13	11	11	12	13	15	11	-	-	152
	Agreement with actual age	-	100%	60%	56%	89%	62%	65%	31%	36%	9%	8%	23%	13%	0%	-	-	41%
Reader 5	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Spain IR	Mean age recorded	-	1.00	2.80	3.00	4.32	5.08	6.00	6.62	8.09	8.64	9.25	9.92	10.47	11.55	-	-	
	2stdev	-	0.00	0.89	1.41	1.16	0.56	1.00	1.01	1.40	1.35	2.11	1.52	1.98	2.59	-	-	
	CV(%)	-	0%	16%	24%	13%	5%	8%	8%	9%	8%	11%	8%	9%	11%	-	-	10%
	Number of age readings	-	3	5	9	19	13	17	13	11	11	12	13	15	11	-	-	152
	Agreement with actual age	-	100%	20%	56%	58%	92%	76%	62%	82%	45%	33%	15%	13%	27%	-	-	51%
Reader 6	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Port LS	Mean age recorded	-	1.00	2.00	2.56	3.84	4.92	5.71	6.62	8.00	7.75	9.17	10.00	10.53	11.55	-	-	
	2stdev	-	0.00	0.00	1.45	1.00	0.99	1.97	1.92	3.58	2.43	2.93	3.16	2.12	2.43	-	-	
	CV(%)	-	0%	0%	28%	13%	10%	17%	15%	22%	16%	16%	16%	10%	11%	-	-	14%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	100%	67%	74%	77%	35%	46%	27%	33%	17%	23%	13%	18%	-	-	43%
Reader 7	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Port AMC	Mean age recorded	-	1.00	2.00	2.56	4.32	6.46	7.53	8.08	8.91	9.58	11.50	11.31	11.47	13.18	-	-	
	2stdev	-	0.00	0.00	1.05	2.67	3.43	3.09	2.88	2.89	1.03	1.60	2.22	2.12	1.21	-	-	
	CV(%)	-	0%	0%	21%	31%	27%	21%	18%	16%	5%	7%	10%	9%	5%	-	-	15%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	100%	56%	42%	38%	41%	15%	9%	42%	8%	23%	27%	64%	-	-	37%
Reader 8	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Irel LB	Mean age recorded	-	1.00	2.20	2.89	3.89	5.08	6.00	6.54	7.45	7.92	8.50	9.46	10.00	10.45	-	-	
	2stdev	-	0.00	0.89	1.20	1.13	1.52	1.41	1.93	3.02	1.59	2.17	2.53	2.14	1.04	-	-	
	CV(%)	-	0%	20%	21%	15%	15%	12%	15%	20%	10%	13%	13%	11%	5%	-	-	13%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	80%	67%	68%	46%	53%	38%	36%	17%	25%	8%	0%	0%	-	-	37%
Reader 9	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Irel EM	Mean age recorded	-	1.00	2.60	3.00	4.11	5.38	6.41	6.85	8.55	8.92	9.67	10.69	11.40	12.27	-	-	
	2stdev	-	0.00	1.10	0.00	0.63	1.30	1.24	1.11	2.88	1.99	1.78	1.71	1.01	1.57	-	-	
	CV(%)	-	0%	21%	0%	8%	12%	10%	8%	17%	11%	9%	8%	4%	6%	-	-	9%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	40%	100%	89%	69%	65%	69%	45%	33%	42%	46%	40%	18%	-	-	58%
Reader 10	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Neth SR	Mean age recorded	-	1.00	3.00	3.00	4.16	5.46	6.06	7.15	7.82	8.50	9.75	9.77	11.07	11.91	-	-	
	2stdev	-	0.00	2.00	1.41	1.00	3.52	1.93	2.14	1.75	2.17	2.84	2.03	3.16	1.66	-	-	
	CV(%)	-	0%	33%	24%	12%	32%	16%	15%	11%	13%	15%	10%	14%	7%	-	-	15%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	40%	56%	74%	62%	47%	38%	55%	42%	25%	23%	33%	18%	-	-	45%
Reader 11	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Neth BC	Mean age recorded	-	1.00	2.00	3.11	3.95	4.77	5.94	6.77	7.73	8.50	9.50	10.31	11.33	12.00	-	-	
	2stdev	-	0.00	0.00	2.33	1.05	1.20	1.65	2.33	3.11	1.81	2.17	2.22	1.63	2.68	-	-	
	CV(%)	-	0%	0%	38%	13%	13%	14%	17%	20%	11%	11%	11%	7%	11%	-	-	14%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	100%	67%	74%	85%	53%	31%	36%	25%	42%	23%	33%	18%	-	-	48%
Reader 12	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Germ AC	Mean age recorded	-	1.33	2.20	2.67	4.11	5.08	5.88	6.77	8.00	8.33	9.83	9.69	10.60	12.18	-	-	
	2stdev	-	1.15	0.89	1.00	0.92	0.55	1.20	1.66	1.55	1.56	1.67	2.50	1.47	1.75	-	-	
	CV(%)	-	43%	20%	19%	11%	5%	10%	12%	10%	9%	8%	13%	7%	7%	-	-	11%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	67%	80%	67%	79%	92%	65%	54%	45%	50%	58%	15%	7%	45%	-	-	54%
Reader 13	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Germ GG	Mean age recorded	-	1.00	2.40	3.33	4.26	5.38	6.71	7.54	8.36	9.42	10.25	11.23	11.27	12.27	-	-	
	2stdev	-	0.00	1.10	1.00	1.47	1.54	1.97	3.12	2.24	2.48	3.32	2.03	2.56	4.66	-	-	
	CV(%)	-	0%	23%	15%	17%	14%	15%	21%	13%	13%	16%	9%	11%	19%	-	-	15%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	60%	67%	58%	54%	29%	23%	55%	33%	8%	23%	33%	36%	-	-	40%
Reader 14	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Denm AT	Mean age recorded	-	1.00	2.00	2.44	3.84	5.85	6.71	7.77	8.91	8.92	10.08	11.00	11.93	11.91	-	-	
	2stdev	-	0.00	0.00	1.76	2.03	2.43	1.84	3.28	2.09	1.59	3.24	1.63	1.19	2.27	-	-	
	CV(%)	-	0%	0%	36%	26%	21%	14%	21%	12%	9%	16%	7%	5%	10%	-	-	15%
	Number of age readings	-	3	5	9	19	13	17	13	11	12	12	13	15	11	-	-	153
	Agreement with actual age	-	100%	100%	67%	47%	31%	35%	15%	18%	42%	8%	62%	67%	45%	-	-	43%
Reader 15	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
Eng PW	Mean age recorded	-	1.00	2.00	2.78	4.05	5.00	5.76	6.85	8.27	8.18	9.25	10.38	10.87	12.09	-	-	
	2stdev	-	0.00	0.00	0.88	1.05	0.00	1.12	2.29	1.57	1.21	3.21	2.89	2.12	2.44	-	-	
	CV(%)	-	0%	0%	16%	13%	0%	10%	17%	10%	7%	17%	14%	10%	10%	-	-	11%
	Number of age readings	-	3	5	9	19	13	17	13	11	11	12	13	15	11	-	-	152
	Agreement with actual age	-	100%	100%	78%	74%	100%	65%	46%	64%	27%	33%	38%	33%	55%	-	-	59%
ALL READERS	Actual age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	0-15
	Mean age recorded	-	1.02	2.27	2.83	4.06	5.22	6.13	6.96	8.13	8.57	9.69	10.37	11.00	11.98	-	-	
	2stdev	-	0.30	1.06	1.31	1.26	1.84	1.89	2.26	2.53	1.92	2.83	2.53	2.35	2.57	-	-	
	CV(%)	-	15%	23%	23%	16%	18%	15%	16%	16%	11%	14%	12%	11%	11%	-	-	15%
	Number of age readings	-	45	75	135	285	195	255	195	165	176	180	195	225	165	-	-	2291
	Agreement with actual age	-	98%	77%	70%	72%	71%	53%	42%	47%	38%	29%	29%	29%	30%	-	-	49%

Table 7.1 **Changes in precision, accuracy and bias between 1996 Horse Mackerel Otolith exchange (set A) and the beginning of this workshop (set G).**

	PRECISION (CV%) #		
Country/reader	**Set A**	**Set G**	**Improvement**
S.Afr MK	7%	6%	1%
Norw HG	12%	10%	2%
Spain PA	7%	9%	-2%
Spain IR	13%	11%	2%
Port LS	16%	14%	2%
Irel EB	17%	15%	2%
Neth SR	18%	19%	-1%
Germ AC	10%	11%	-1%
Average	13%	12%	1%

Low percentage indicates a high precision and high percentage indicates a low precision. Improvement in precision is obtained by reducing the percentage CV.

	ACCURACY (agreement with actual age) @		
Country/reader	**Set A**	**Set G**	**Improvement**
S.Afr MK	71%	75%	4%
Norw HG	44%	51%	7%
Spain PA	49%	48%	-1%
Spain IR	22%	41%	19%
Port LS	41%	41%	0%
Irel EB	35%	39%	4%
Neth SR	26%	23%	-3%
Germ AC	49%	45%	-4%
Average	42%	45%	3%

@ High agreement indicates a high accuracy and low agreement indicates a low accuracy.

unit=years	BIAS (weighted mean over ages 9-13) $		
Country/reader	**Set A**	**Set G**	**Improvement**
S.Afr MK	-0.95	-0.66	0.29
Norw HG	-0.55	-0.86	-0.31
Spain PA	-0.97	-0.73	0.24
Spain IR	-1.01	-1.24	-0.23
Port LS	-1.59	-1.19	0.40
Irel EB	-0.68	-0.74	-0.06
Neth SR	0.43	-0.61	-1.04
Germ AC	-0.43	-1.12	-0.69
Average	-0.72	-0.89	-0.18

$ Negative bias indicates an underestimation of mean age.
Improvement is positive if underestimation of age is decreased and negative if increased.

Table 7.2 **Changes in precision, accuracy and bias during the Workshop meeting. The final set K is compared to the mean of sets G and I, representing otoliths of the first and second half of the year. Set G and I were read at the beginning and set K at the end of the Workshop meeting.**

		PRECISION (CV) #				
Reader nr	Country/reader	Set G	Set I	mean Sets G & I	Set K	Improvement
1	*S.Afr MK*	6%	8%	7%	8%	-1%
2	*Norw HG*	10%	14%	12%	11%	1%
3	*Spain PA*	9%	12%	11%	9%	2%
4	*Spain QP*	14%	17%	16%	14%	2%
5	*Spain IR*	11%	13%	12%	10%	2%
6	*Port LS*	14%	18%	16%	14%	2%
7	*Port AMC*	12%	18%	15%	15%	0%
8	*Irel EB*	15%	18%	17%	13%	4%
9	*Irel EM*	15%	12%	14%	9%	5%
10	*Neth SR*	19%	16%	18%	15%	3%
11	*Neth BC*	12%	17%	15%	14%	1%
12	*Germ AC*	11%	11%	11%	11%	0%
13	*Germ GG*	15%	15%	15%	15%	0%
14	*Denm AT*	16%	16%	16%	15%	1%
15	*Eng PW*	11%	15%	13%	11%	2%
1-15	***All readers***	15%	20%	18%	15%	3%

Low percentage indicates a high precision and high percentage indicates a low precision.
Improvement in precision is obtained by reducing the percentage CV.

		ACCURACY (agreement with actual age) @				
Reader nr	Country/reader	Set G	Set I	mean Sets G & I	Set K	Improvement
1	*S.Afr MK*	75%	54%	65%	74%	10%
2	*Norw HG*	51%	49%	50%	56%	6%
3	*Spain PA*	48%	60%	54%	53%	-1%
4	*Spain QP*	33%	23%	28%	41%	13%
5	*Spain IR*	41%	28%	35%	51%	17%
6	*Port LS*	41%	32%	37%	43%	7%
7	*Port AMC*	38%	29%	34%	37%	4%
8	*Irel EB*	39%	28%	34%	37%	4%
9	*Irel EM*	42%	47%	45%	58%	14%
10	*Neth SR*	23%	36%	30%	45%	16%
11	*Neth BC*	38%	50%	44%	48%	4%
12	*Germ AC*	45%	59%	52%	54%	2%
13	*Germ GG*	26%	43%	35%	40%	6%
14	*Denm AT*	35%	36%	36%	43%	8%
15	*Eng PW*	48%	56%	52%	59%	7%
1-15	***All readers***	42%	42%	42%	49%	7%

@ High agreement indicates a high accuracy and low agreement indicates a low accuracy.

unit = years		BIAS (weighted mean over ages 9-13) $				
Reader nr	Country/reader	Set G	Set I	mean Sets G & I	Set K	Improvement
1	*S.Afr MK*	-0.66	0.24	-0.21	-0.16	0.05
2	*Norw HG*	-0.86	-0.83	-0.85	-0.50	0.35
3	*Spain PA*	-0.73	-0.40	-0.57	-0.70	-0.14
4	*Spain QP*	-1.21	1.08	-0.06	-1.37	-1.31
5	*Spain IR*	-1.24	0.00	-0.62	-1.06	-0.44
6	*Port LS*	-1.19	-0.76	-0.98	-1.21	-0.24
7	*Port AMC*	-0.95	-1.75	-1.35	0.37	1.72
8	*Irel EB*	-0.74	-1.63	-1.19	-1.73	-0.55
9	*Irel EM*	-0.56	-0.08	-0.32	-0.41	-0.09
10	*Neth SR*	-0.61	-1.00	-0.81	-0.81	-0.01
11	*Neth BC*	-0.89	-0.28	-0.59	-0.67	-0.09
12	*Germ AC*	-1.12	-0.40	-0.76	-0.90	-0.14
13	*Germ GG*	-0.45	-1.38	-0.92	-0.13	0.79
14	*Denm AT*	-0.80	-1.56	-1.18	-0.21	0.97
15	*Eng PW*	-1.33	-0.32	-0.83	-0.85	-0.02
1-15	***All readers***	-0.89	-0.60	-0.75	-0.69	0.06

$ Negative bias indicates an underestimation of mean age.
Improvement is positive if underestimation of age decreased and negative if underestimation increased.

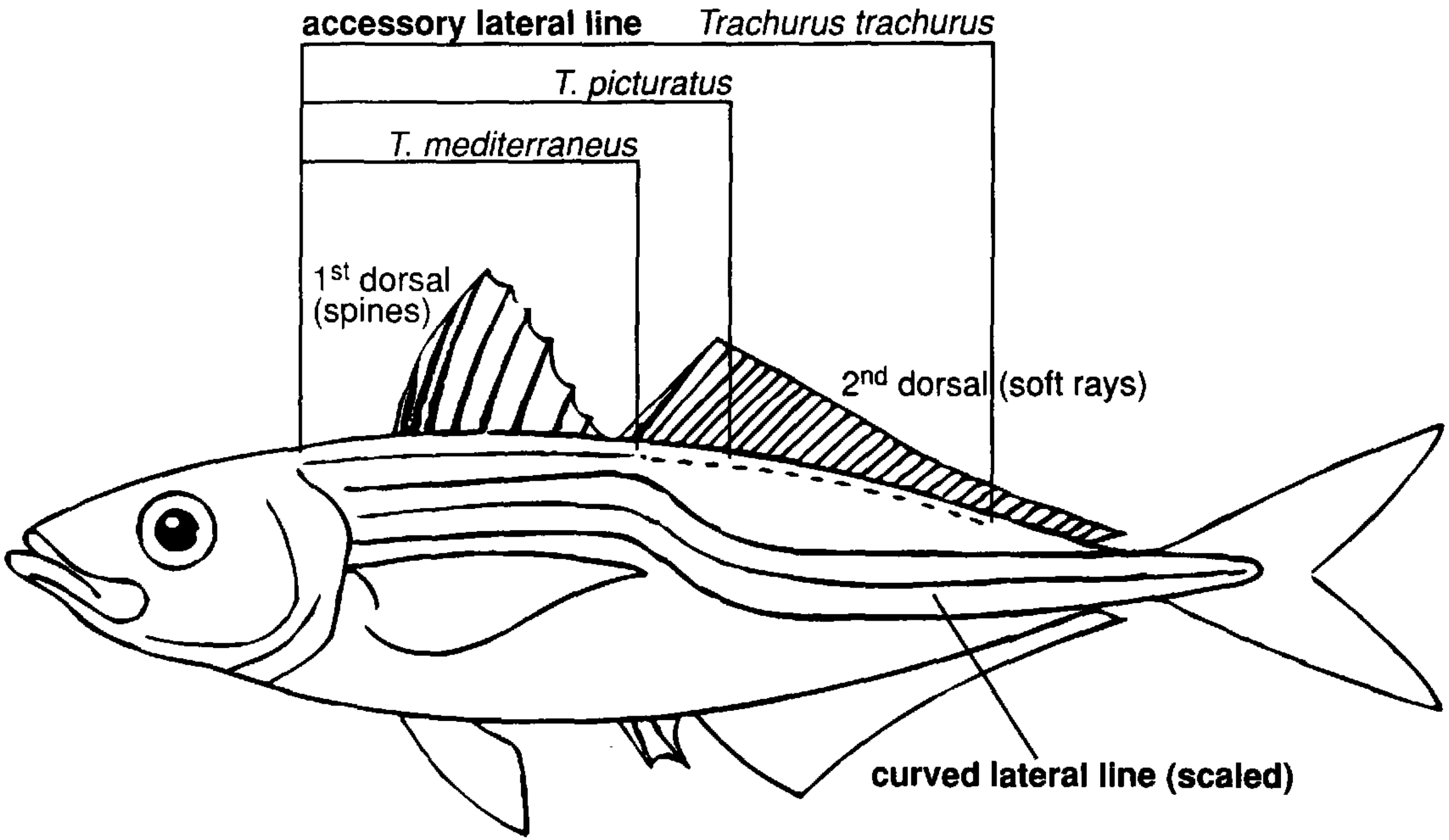

Fig. 2.1: Main features for differentiating the three North Atlantic species of the genus *Trachurus*. After Nümann 1959, modified.

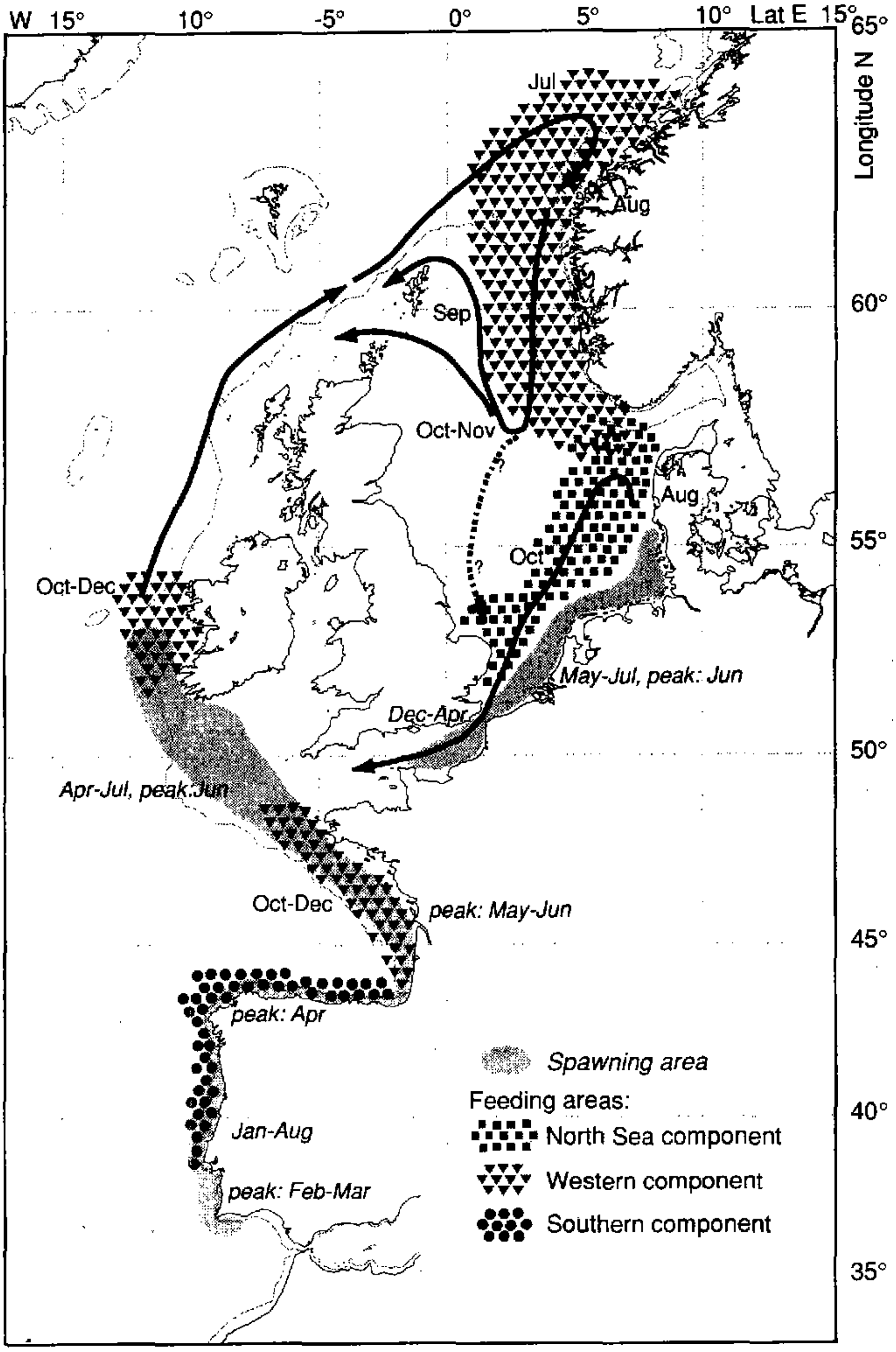

Fig. 2.2: Schematic outline of assumed migration routes, spawning and feeding areas for the three Horse Mackerel stocks. Depth line drawn is the 200 m contour. For over-wintering areas see Fig. 2.3. From ICES 1992, redrawn.

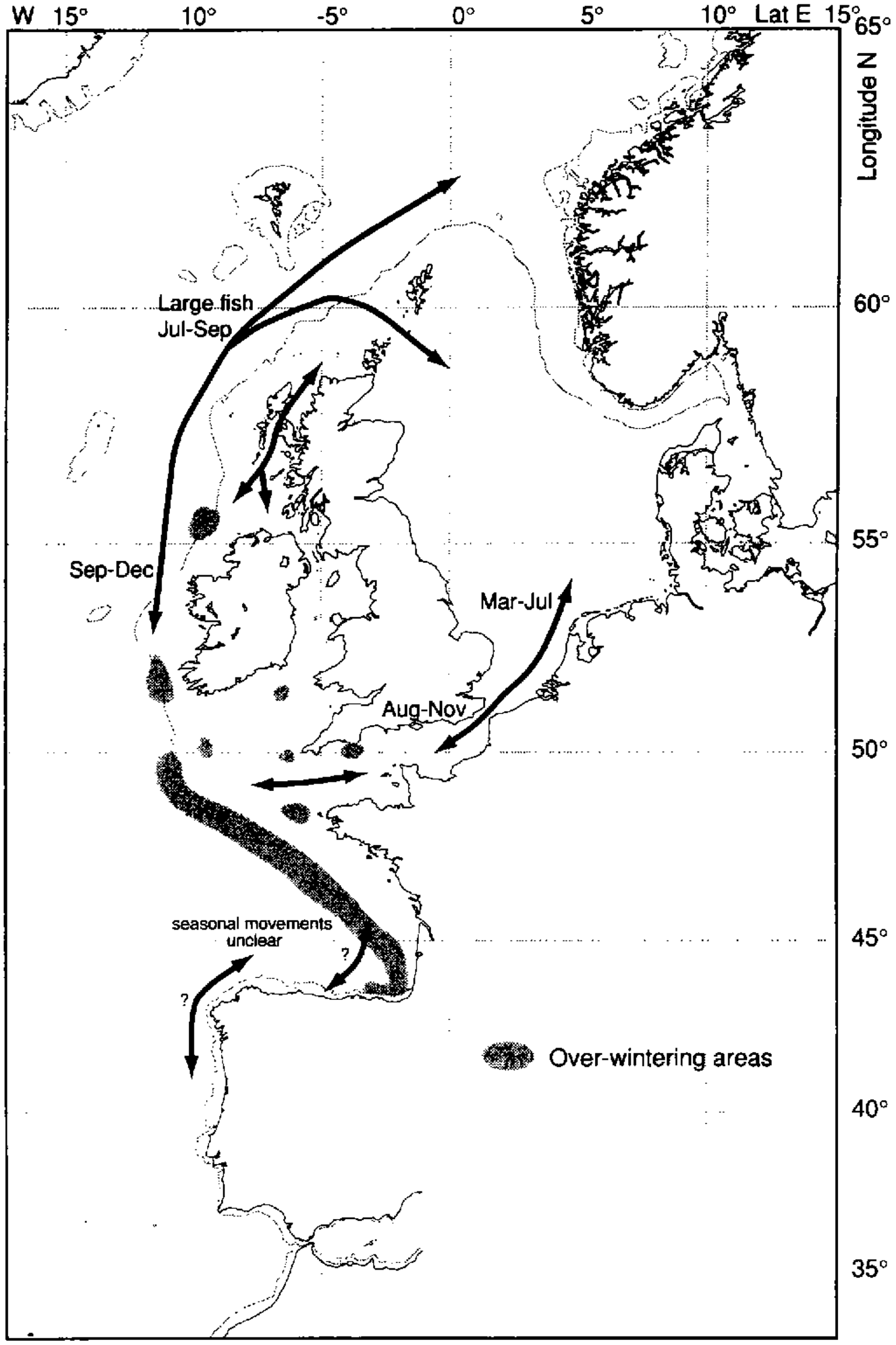

Fig. 2.3: Schematic outline of over-wintering areas and assumed migration routes, Depth line drawn is the 200 m contour. For feeding and spawning areas, see Fig. 2.2. From Eaton 1983, redrawn.

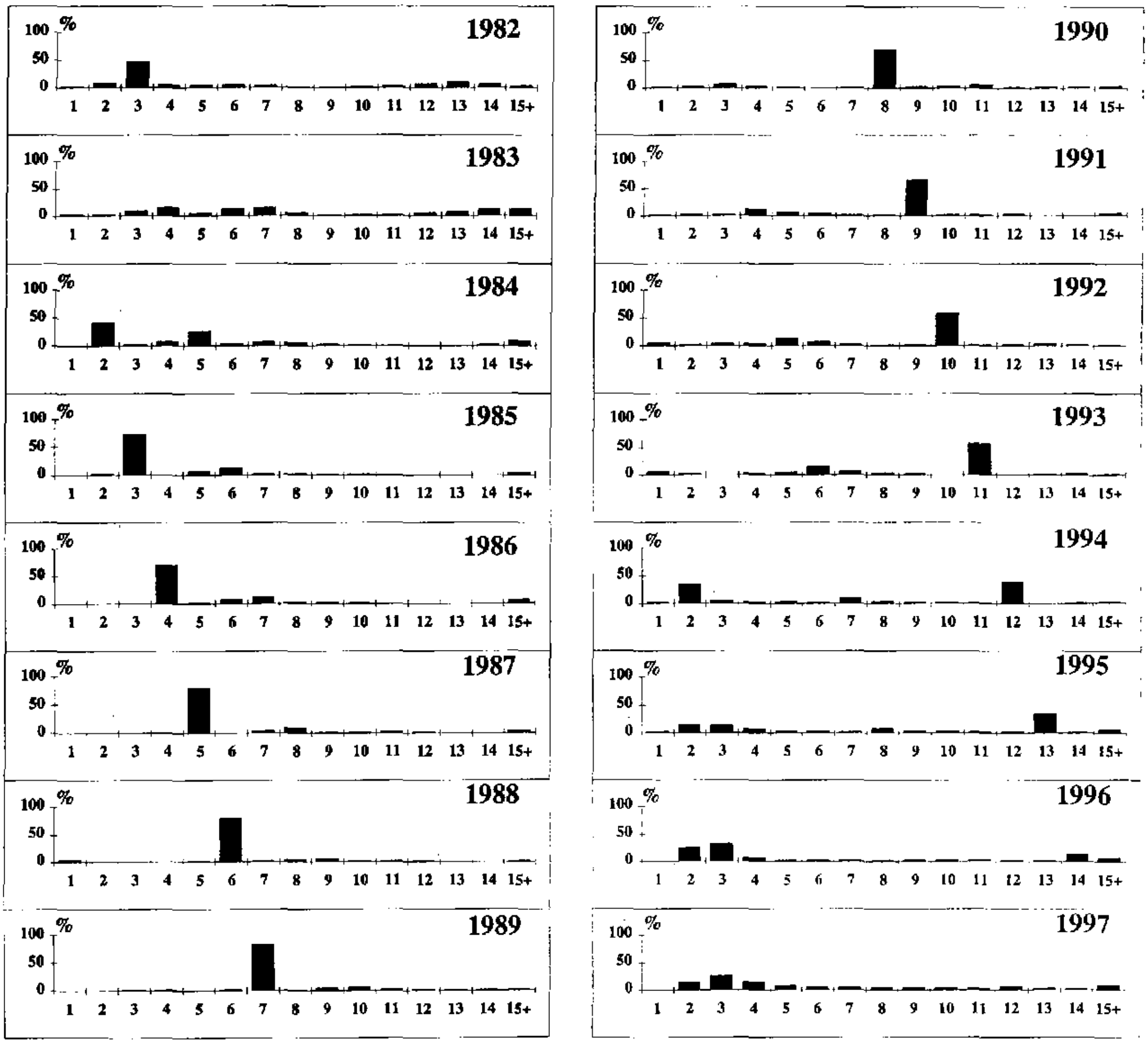

Figure 2.4 The age composition of the WESTERN HORSE MACKEREL in the international catches from 1982-1997.

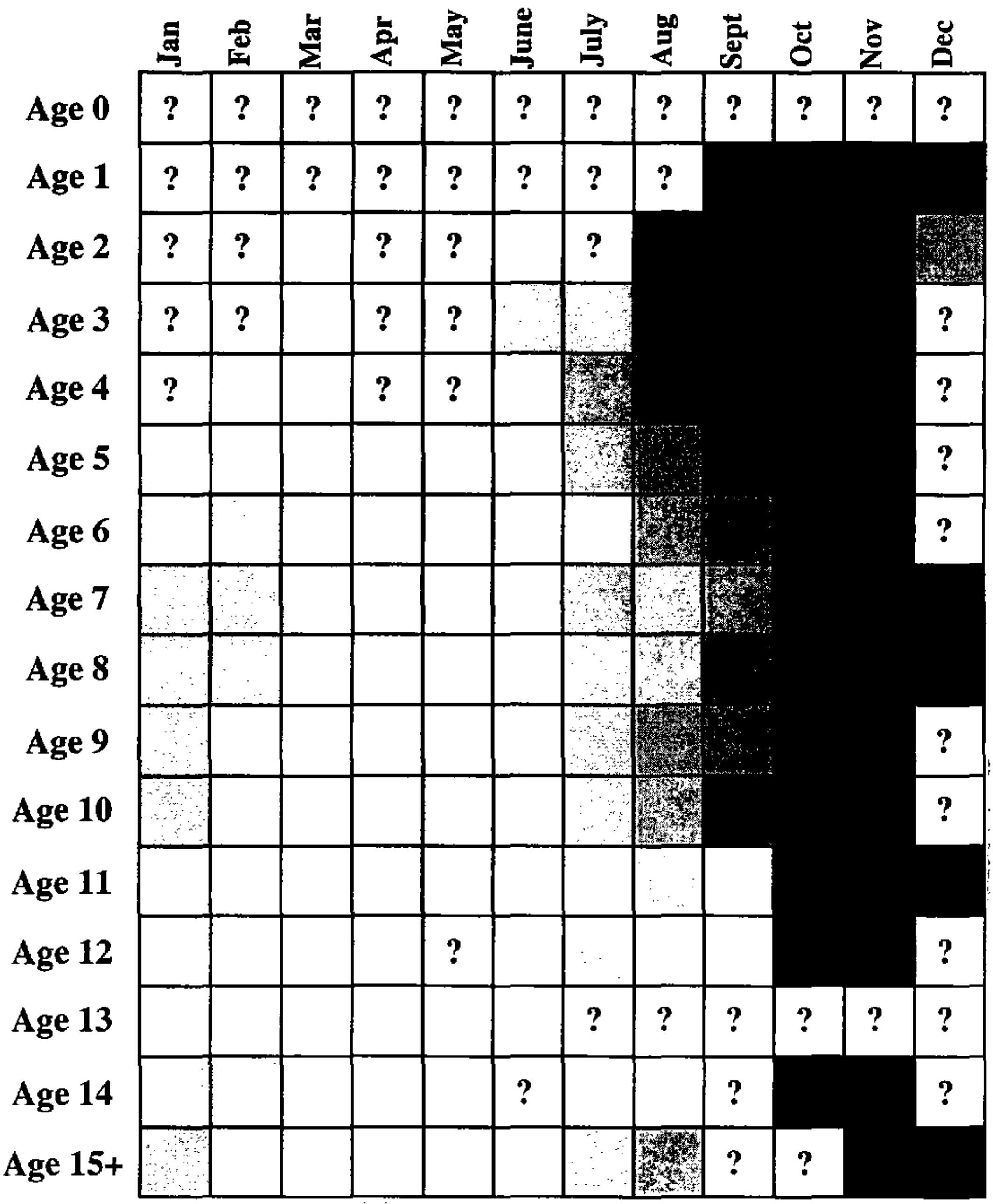

Figure 2.5 The proportion of horse mackerel having otoliths with an opaque edge given by age group and by month of catch for ICES **Divisions VIIa-c,e-k**. A '?' is shown if less than 10 otoliths were available. A white square indicates that all otoliths have a hyaline ege. Based on Dutch otolith edge interpretation on otoliths from fish samples collected during 1990 - 1997.

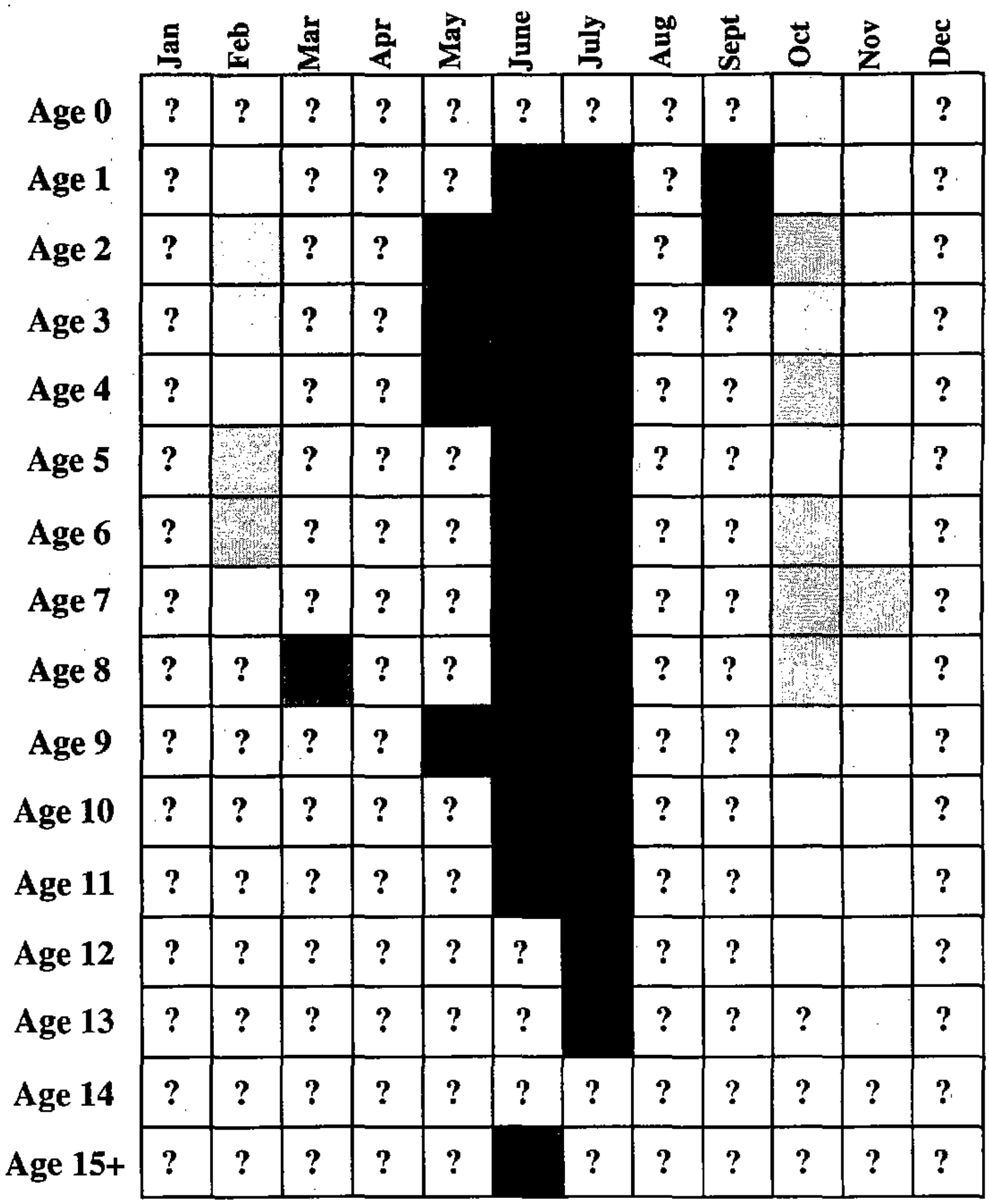

Figure 2.6 The proportion of horse mackerel having otoliths with an opaque edge given by age group and by month of catch for ICES **Division IXa.** A '?' is shown if less than 10 otoliths were available. A white square indicates that all otoliths have a hyaline ege. Based on Portuguese and Spanish otolith edge interpretation on otoliths from fish samples collected during 1990 - 1997.

HORSE MACKEREL OTOLITH EXCHANGE 1996 SET A (revised)

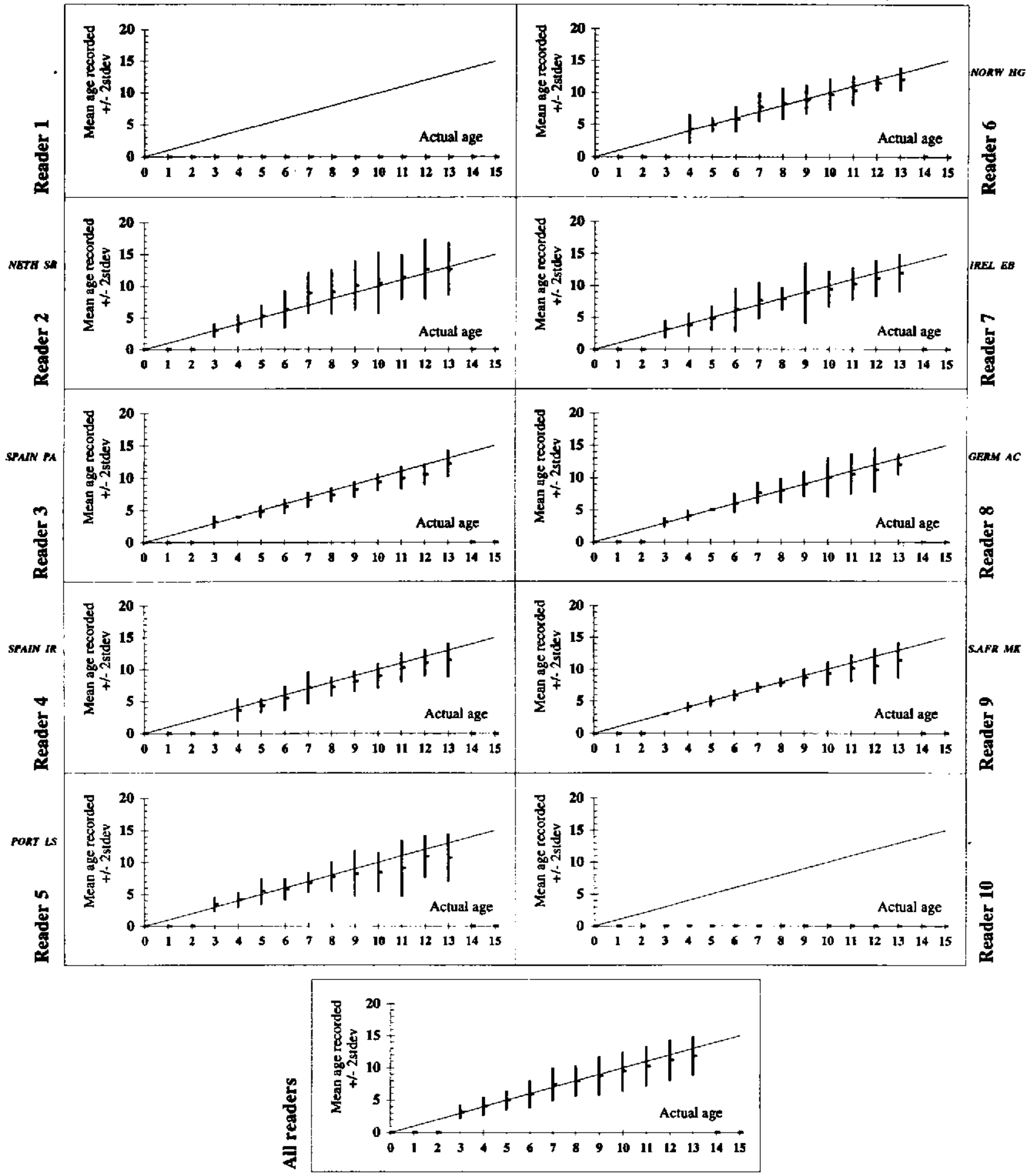

Figure 3.1 In above age bias plot the mean age recorded +/- 2stdev of each reader and of all age readers combined is plotted against the actual age.

HORSE MACKEREL OTOLITH EXCHANGE 1996 SET A (revised)

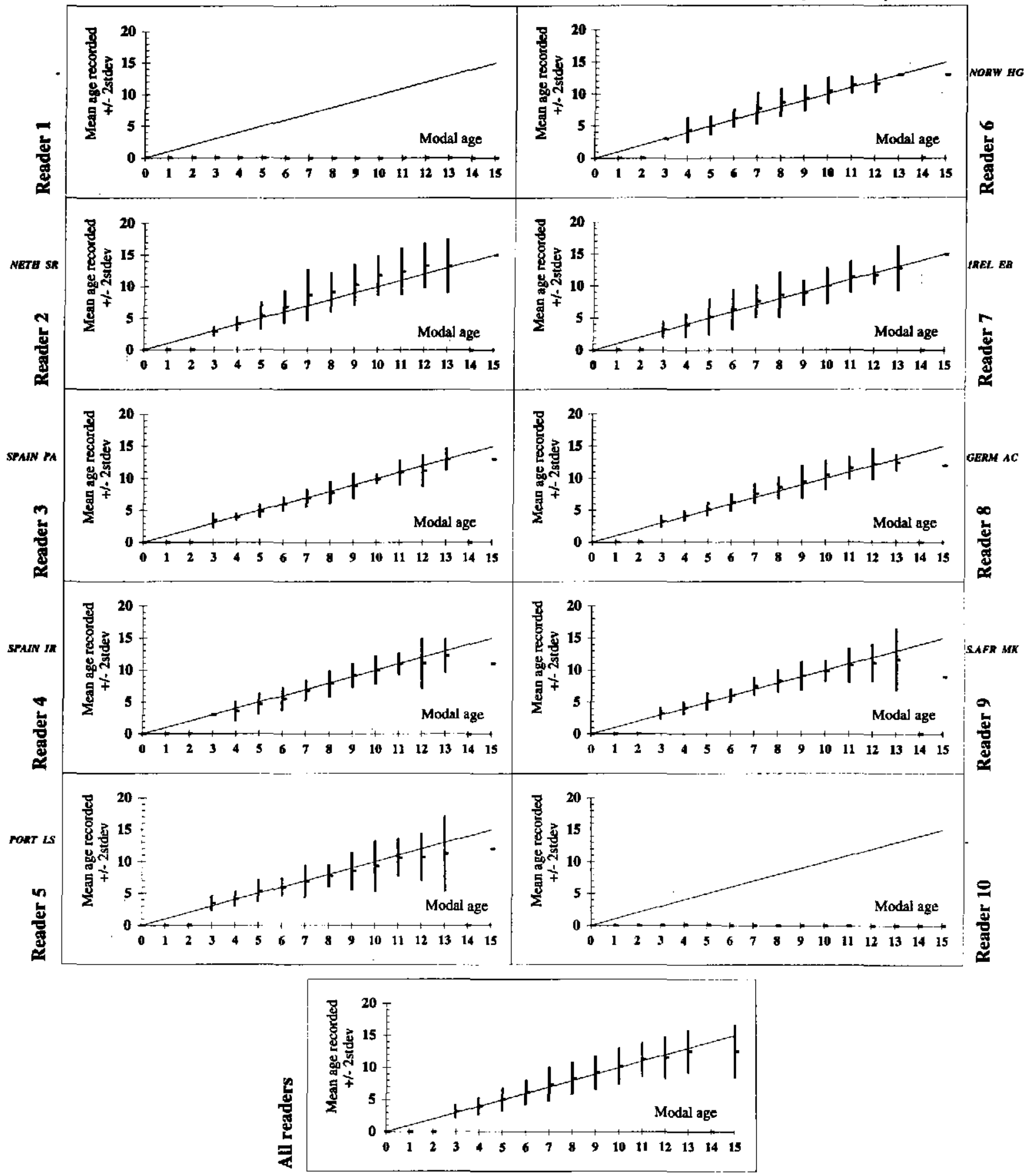

Figure 3.2 **In above age bias plot the mean age recorded +/- 2stdev of each reader and of all age readers is plotted against the modal age.**

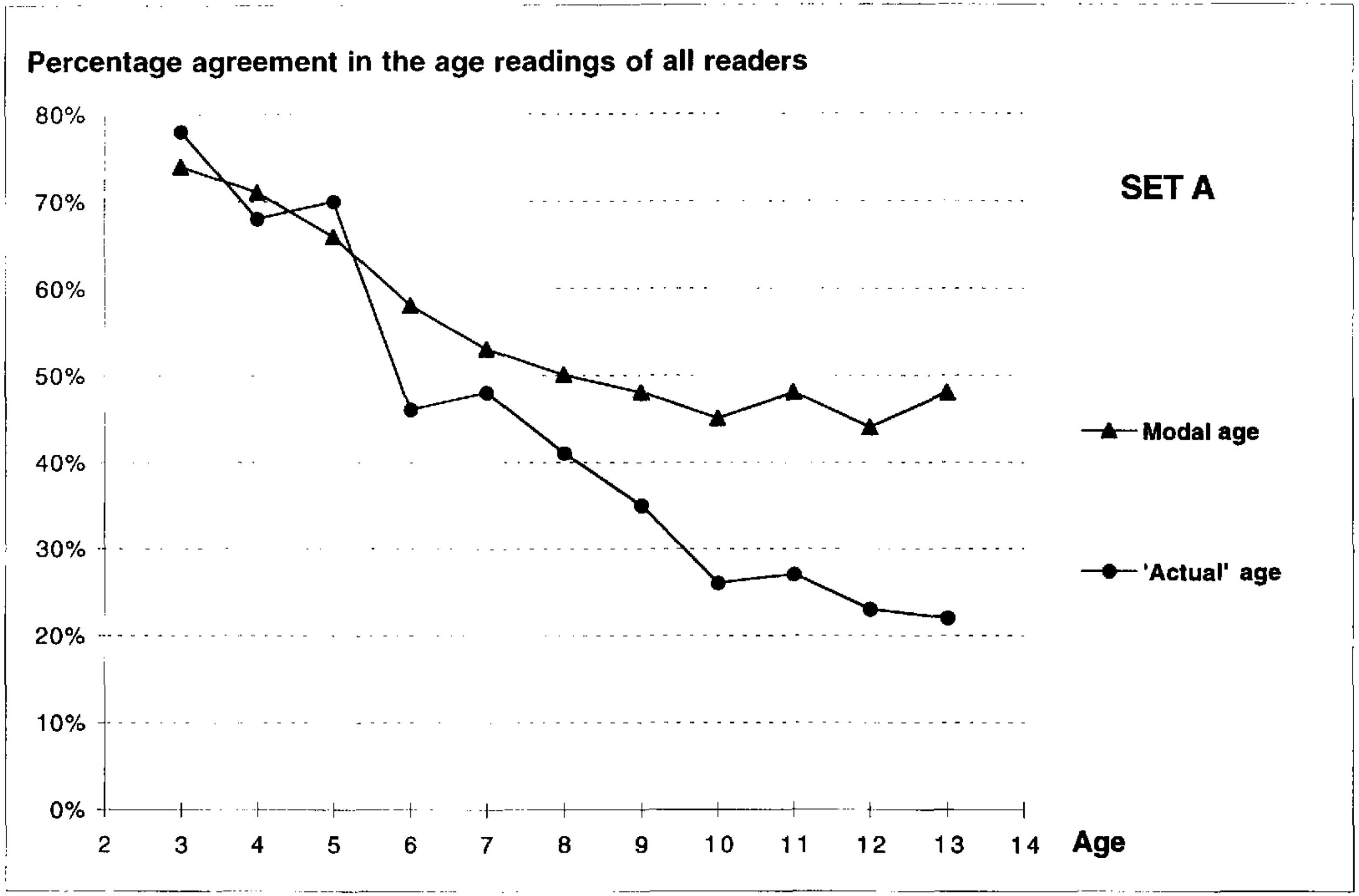

Figure 3.3 1996 Horse Mackerel Otolith Exchange (revised from Eltink, 1997).
The percentage of agreement in the age readings of all readers obtained from comparisons to 'actual' and to modal age.

HORSE MACKEREL OTOLITH EXCHANGE 1996 SET B (revised)

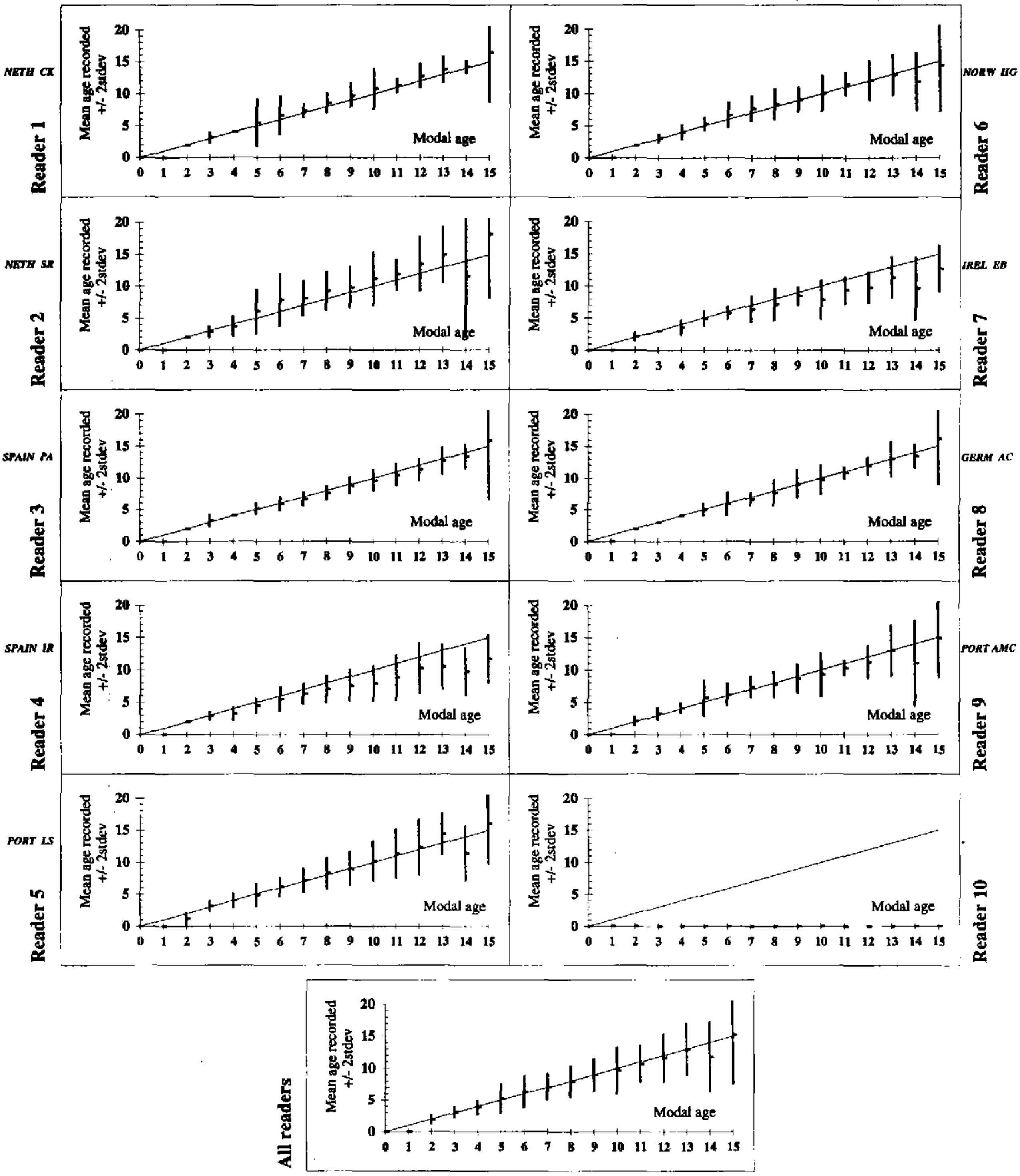

Figure 3.4 In above age bias plot the mean age recorded +/- 2stdev of each reader and of all age readers is plotted against the modal age.

Horse Mackerel Otolith SET G (WKHMO, Lowestoft, 15-19 January 1999)

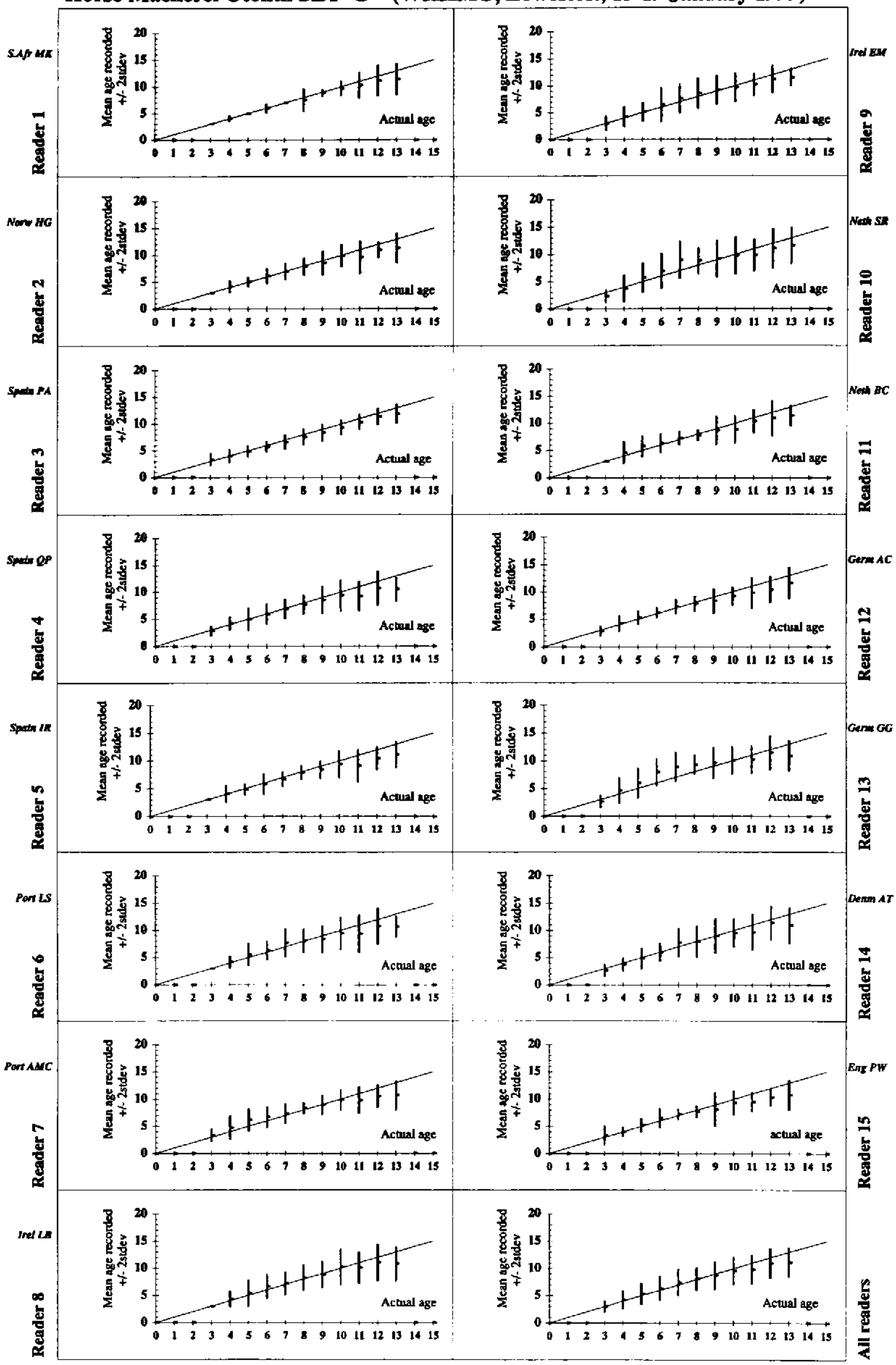

Figure 5.1 In above age bias plots the mean age recorded +/- 2stdev of each age reader and all readers combined is plotted against the actual age.

Horse Mackerel Otolith SET I (WKHMO, Lowestoft, 15-19 January 1999)

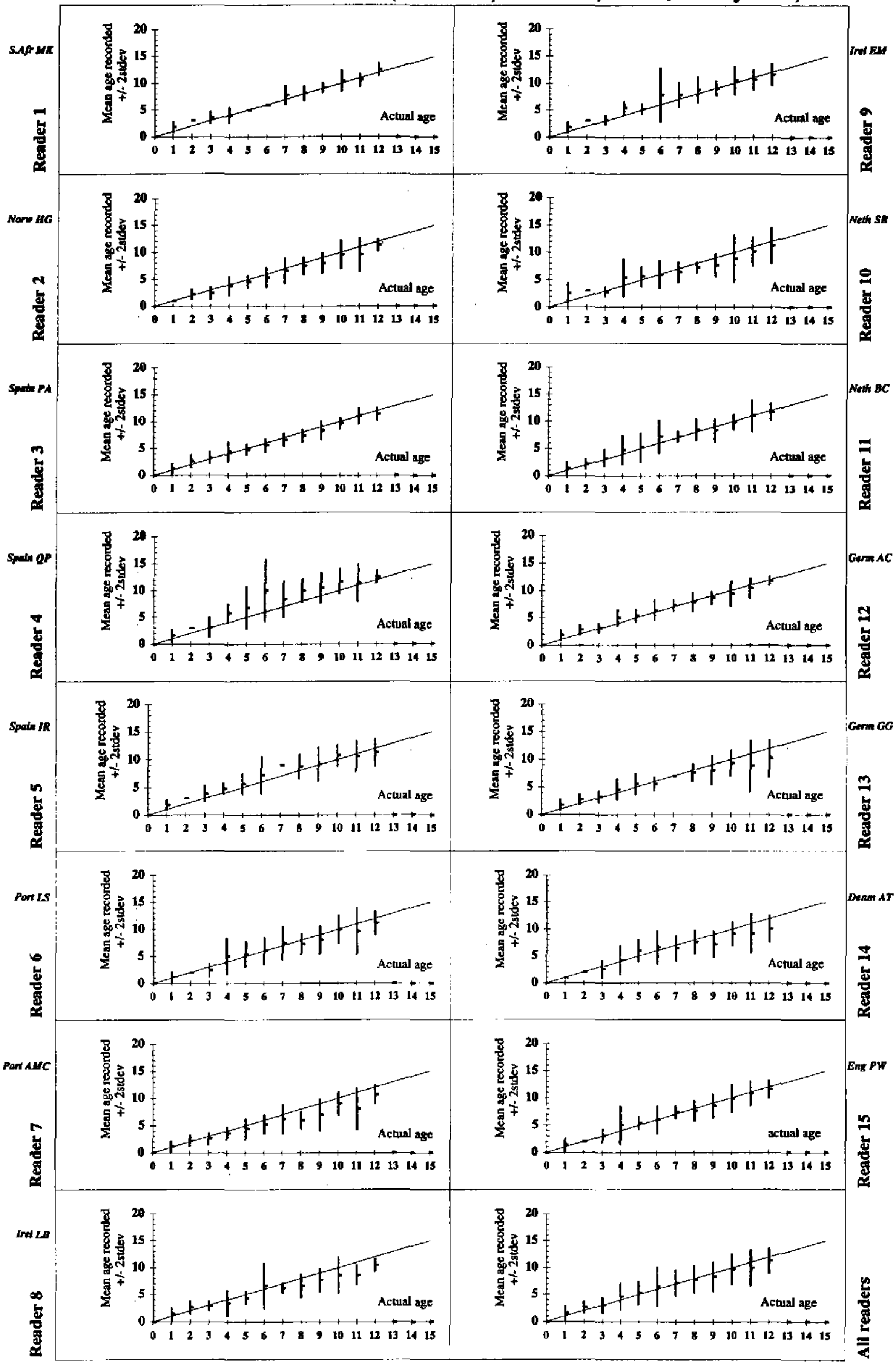

Figure 5.2 In above age bias plots the mean age recorded +/- 2stdev of each age reader and all readers combined is plotted against the actual age.

Horse Mackerel Otolith SET K (WKHMO, Lowestoft, 15-19 January 1999)

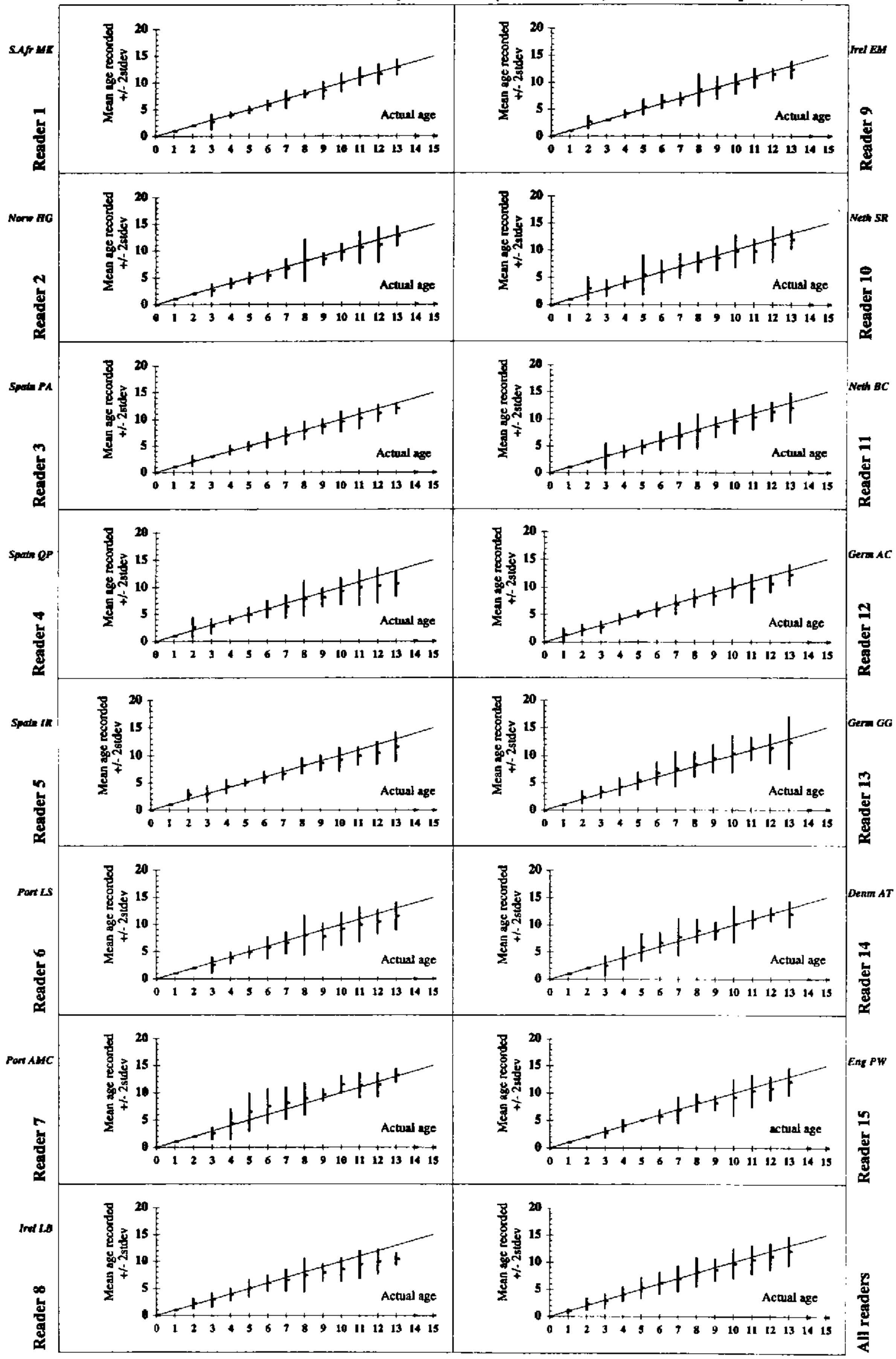

Figure 6.1 In above age bias plots the mean age recorded +/- 2stdev of each age reader and all readers combined is plotted against the actual age.

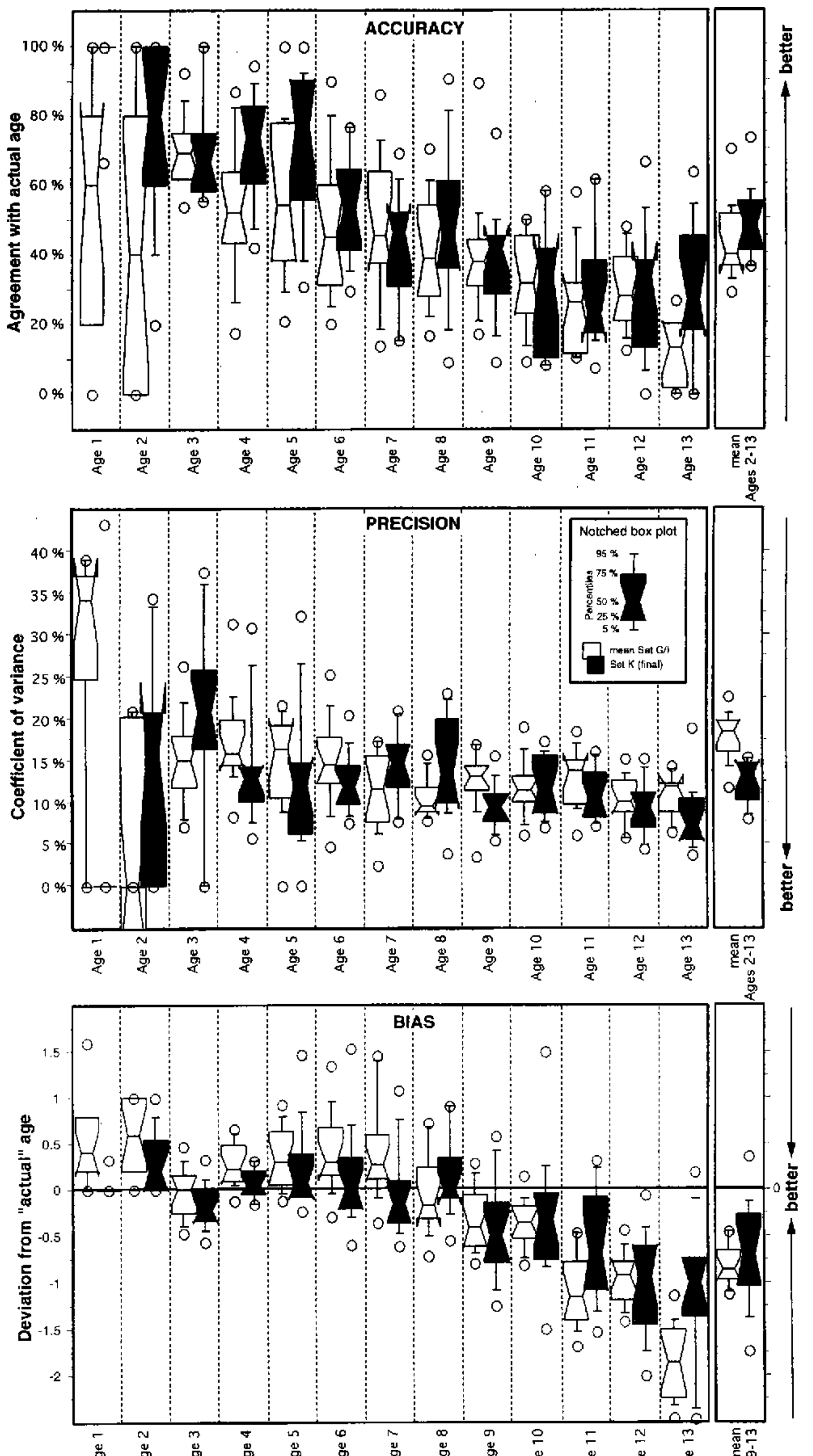

Fig. 7.1: Comparison of accuracy (upper panel), precision (middle panel) and bias (lower panel) for all readers versus actual age between the first (mean of results for otolith sets G and I, white) and last readings (set K, grey).

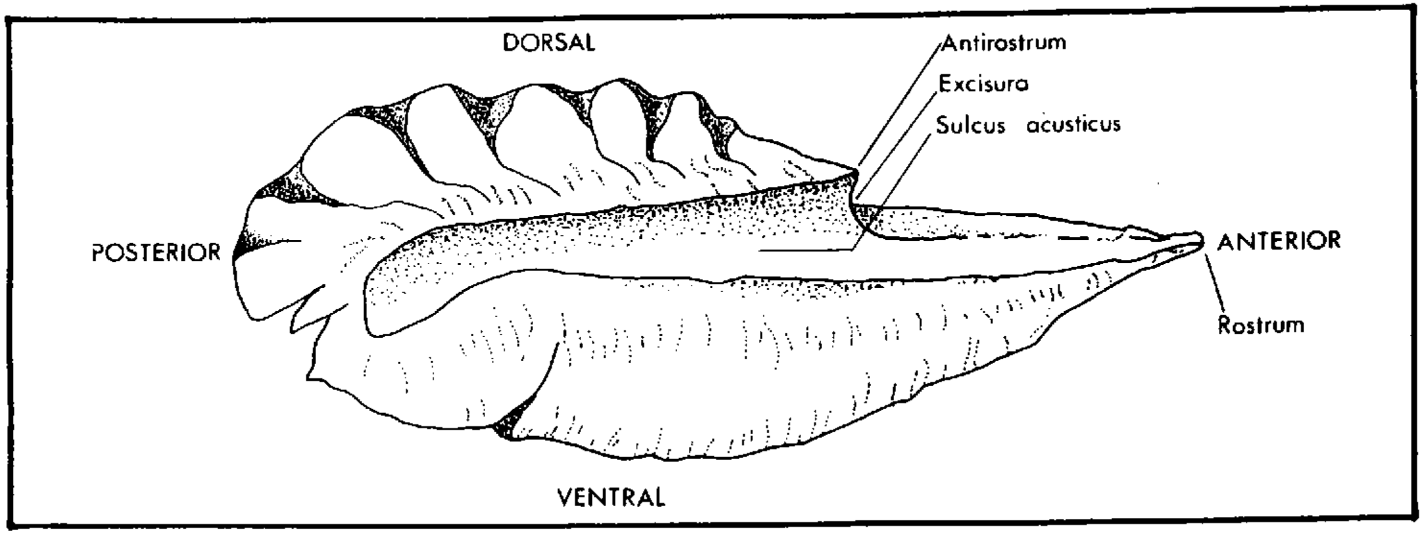

Figure 9.1 Medial view of left otolith (internal, convex side up) (from Geldenhuys 1973).

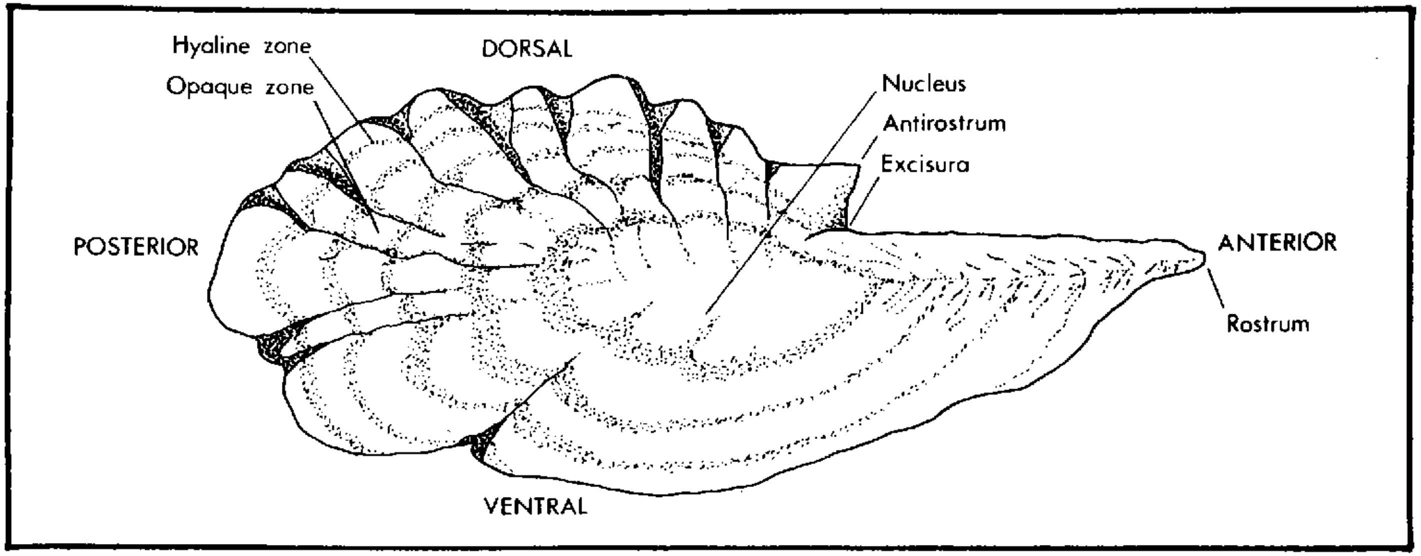

Figure 9.2 Lateral view of right otolith (external, concave side up) (from Geldenhuys 1973).

ADDENDUM

EFFECTS OF AGE READING ERRORS ON THE ASSESSMENT OF HORSE MACKEREL

1 SUMMARY

The report of the Horse Mackerel Otolith Workshop 1999 provided information on the precision, accuracy and absolute bias in the age readings both by age reader and for all age readers combined, because otoliths of 'known' age were used. One of the last terms of reference of this Workshop was to "Determine to what extent age reading errors affect stock assessments of horse mackerel". However, this term of reference could not be addressed at the Workshop meeting, because the final results on precision, accuracy and absolute bias became only available at the end of the Workshop. Therefore this subject will be dealt with in this paper.

The effect of age reading errors on the horse mackerel assessment is investigated by applying different levels of precision (coefficient of variation of 5%, 10% and 15%) and by applying an absolute bias in age reading as observed at the workshop. This absolute bias or underestimation of age starts at age 7 and is gradually increasing to a 1-year difference at age 13. The factor between largest and smallest recruitment also affects the level of errors in the assessment. Therefore 3 different factors were used to determine the errors in the assessment (factor 1, which implies constant recruitment and the factors 4 and 16). The assessments are tuned to absolute spawning stock biomass values as is done for the western horse mackerel with spawning stock biomass values obtained from egg surveys. The effects on the assessment caused by the age reading errors are expressed in percentage over- or underestimation of recruitment, spawning stock biomass, fishing mortality, population at age and selection pattern. This analysis only indicates the effects caused by the errors in age reading, but not by errors in biological sampling, proportion mature at age, fecundity and egg sampling for the biomass estimate.

Age reading errors as were observed at the end of the 1999 Horse Mackerel Otolith Workshop (CV=15% with bias) have the following estimated effects on the assessment of horse mackerel:

Below average recruitment might be over 200% overestimated and above average recruitment up to 35% underestimated. In addition the recruitment of the most recent years will be overestimated (gradually increasing up to 20% in the last year). The assessment will provide only very smoothed recruitment estimates and the difference between highest and lowest observed recruitment might be 5 times higher.

Fishing mortality (F) will be 1-9% overestimated except in the last two or three years, when it might be slightly underestimated.

Spawning stock biomass (SSB) will be 0-7% underestimated except in the last two or three years, when it might be slightly overestimated.

The population at age in the last year will show the highest overestimation in the younger age groups, which gradually decreases up to age 10, becomes an underestimation from age 11 onwards and the 15+ age group shows a sudden increase in the underestimation. There is an additional effect of overestimating weak year classes and underestimating strong year classes.

The fitted selection pattern in the last year will become dome shaped because of the bias. The highest selection is obtained at approximately age 7 or 8 (approximately 20-25% overestimation).

The effects of observed age reading errors on the assessment of horse mackerel do not explain the problems in assessing this stock. Factors such as the assumption of natural mortality, proportion mature at age, spawning stock biomass estimates from egg surveys, age sampling by area/period, raising of age compositions to international catches, etc. are likely to have a larger impact on the assessment.

2 INTRODUCTION

A Horse Mackerel Otolith Workshop [WKHMO] (Chairman: A. Eltink, the Netherlands) was held in Lowestoft, UK from 15-19 January 1999 to:

a) improve the quality of horse mackerel age readings;
b) prepare a synopsis of the biology of the species (stocks, migrations, spawning, feeding, maturity, growth, etc.);
c) prepare an overview on how the ageing technique was validated;
d) review the sample processing methods;
e) prepare a manual for age reading (date of birth, interpretation of rings and edges, guidelines on how the best ageings can be achieved, etc.); with the objective of improving expertise and training and ensuring that new age readers are well calibrated against experienced age readers in other institutes;
f) compile available information on when translucent and opaque otolith edge structures occur by month and by age group for both western and southern horse mackerel stocks;
g) carry out an exercise to estimate the precision, accuracy and bias from an age reading comparison on otoliths of known age to be carried out at the end of the workshop to demonstrate the improvements;
h) make recommendations on how to improve the age reading quality;
i) determine to what extent age reading errors affect stock assessments of horse mackerel;
j) obtain a peer review of the Workshop report from the appropriate Assessment Working Groups prior to the 1999 Annual Science Conference.

The second last term of reference to "Determine to what extent age reading errors affect stock assessments of horse mackerel" could not be addressed at this Workshop meeting (ICES, 1999a). This was because the results on precision, accuracy and absolute bias became only available at the end of the Workshop. Therefore this subject will be dealt with in this separate paper, which is an *addendum* to the report of the Horse Mackerel Otolith Workshop.

At the end of the 1999 Horse Mackerel Otolith Workshop the results of the age readings of otolith set K provided information on the level of precision, accuracy and bias that could be achieved by experienced and inexperienced individual age readers and by all readers combined (ICES, 1999a). The observed bias at the 1999 Workshop can be taken as absolute bias, since the age readings were compared to 'actual' age (ICES, 1999a). Absolute bias is defined as a systematical over- or underestimation of age compared to the true age. The following basic assumption is related to 'actual' age. During the 1985-1995 the 1982 year class has been extremely abundant in the international catches. Furthermore, the other year classes have been very weak, especially the 1981 and 1983 year classes. It should be noted that these adjacent year classes were also absent during the earlier years of collection (1984-1986). During this period these fish were young and relatively easy to age. It was assumed that during this period the ages have been estimated with a high accuracy and precision, and that reader-bias was not significant, because the actual strength of the 1982 year class was not yet known. When the year of catch is known and when the majority of the otoliths taken are of this 1982 year class, the age readings have a very high probability that they agree with the true age. Therefore, these otoliths of the 1982 year class had been regarded as otoliths of 'known' or 'actual' age.

The information of on both precision and absolute bias provides a unique opportunity to evaluate the effect of age reading errors on the assessment of horse mackerel. This is done by comparing assessments that are based on catch in numbers at age, which either include or do not include age reading errors. Such errors can be of two forms: errors that affect precision, or reproducibility of individual measurements on a given structure, and errors that affect accuracy, or the proximity of the age estimate to the true value (Wilson *et al.*, 1987). These two forms of error are not necessarily linked. In this study either one or both types of errors combined are used.

An artificial population of horse mackerel in numbers at age and spawning stock biomass (SSB) together with its catches at age was calculated over a 40-year period for detecting the effect of age reading errors on the assessment. The Integrated Catch Analysis program (ICA 1.4) was able to recalculate the same population numbers at age by using only the catch in numbers at age and the SSB information. The differences between both assessments are caused by age reading errors, if the catch in numbers at age data either do or do not include age reading errors. The calculated population in numbers at age, fishing mortality (F), recruitment (R), selection pattern, population at age, etc. have been compared with the original information to assess the effects of age reading errors on the stock assessment.

The factor difference between the highest and the lowest annual recruitment appeared to affect the assessment and this effect is also evaluated.

3 MATERIAL AND METHODS

This section describes how known age reading errors as precision and absolute bias are converted into normal distributions, which reflect these age reading errors. It is explained how true catch in numbers at age data are converted into catch in numbers at age data that reflect these age reading errors and how the effects of these errors are evaluated.

Precision

At the end of the 1999 Horse Mackerel Otolith Workshop the results of the age readings of otolith set K provided information on the level of precision that could be achieved by experienced and inexperienced individual age readers and by all readers combined (ICES, 1999a). The precision in the age readings was expressed as the coefficient of variation (CV) at age group and a weighted mean CV was calculated over all age groups as an indicator of precision in age reading for each reader as well as for all readers combined. The CV by 'actual' age group was calculated as follows:

$$CV = STDEV / x$$

where STDEV is the standard deviation of the age readings recorded and x is the mean age recorded for that particular 'actual' age. The mean CV of the age readings of set K was 15% for all readers combined. A CV of 15% was also achieved from age readings of set G of the Workshop. The standard deviations of the age readings of set G and K are very similar (Figure 1) and a smoothed curve has been drawn to obtain standard deviations at age and therefore also CV's at age representing the precision of age reading at the end of the Workshop. The smoothed curve of standard deviations maintained a mean CV of 15% over ages 1-13 as in set K. This corresponded to CV's at age nearly linearly decreasing from 21% at age 1 to 10% at age 13. The standard deviations at age for the mean CV's of 10% and 5% have been obtained by downscaling (Figure 1).

The information on standard deviations at age (Figure 1) was used to produce normal distributions of the age reading errors. The following four different levels of CV were used:

CV = 0% to simulate the absence of age reading errors in precision;
CV = 5% as highest achievable level of precision (6% was achieved by the best reader at the Workshop);
CV = 10% was assumed as the mean level of precision, which all readers might achieve in future;
CV = 15% was achieved by all inexperienced and experienced age readers at the end of the Workshop.

Absolute bias

The results of the age readings of otolith set K also provided information on the accuracy and bias achieved by all readers combined (ICES, 1999a). The observed bias can be taken as absolute bias, since the age readings were compared to 'actual' age (see for explanation of 'actual' age the introduction of this paper and ICES, 1999a). Figure 2 shows the mean age recorded for each 'actual' age for otolith set K of the 1999 Workshop and set A of the 1996 Otolith Exchange (Eltink, 1997). During the 1999 Workshop no improvement could be made regarding the reduction of bias as was observed in the 1996 Otolith Exchange. Therefore, the following two levels of absolute bias are used in the calculations:

No bias to show the improvement in the stock assessment, if there would be no bias.

Bias as observed in otolith sets K and A: the bias starts at age 7 and gradually increases to one year of underestimation at age 13 or two years of underestimation at age 20 (Figure 2).

Normal distributions of age reading errors

Normal distributions of the age reading errors were constructed by age group up to a 20+ age group. These distributions included either one or two forms of age reading errors (only precision or precision combined with absolute bias). Input for the calculation of the normal distributions was age, STDEV and absolute bias, if necessary. No age reading errors were assumed to occur for age 0.

Figure 3 shows the three created normal distributions of the age reading errors based on the mean CV of 5%, 10% and 15% for ages 0 to 15 (ages 16 to 20 are not shown).

Figure 4 shows the three created normal distributions of age reading errors based on the mean CV of 5% including bias, 10% including bias and 15% including bias for ages 0 to 15 (ages 16 to 20 are not shown).

Artificial horse mackerel population

Artificial horse mackerel populations were created for the purpose of creating true catch in number data and for the purpose of calculating SSB values for tuning. True catch in numbers at age data have been converted into catch in numbers at age data that do include the age reading errors in order to be able evaluate the effects on the assessment. Artificial populations were created based on the following assumptions:

Natural mortality (M) equal to 0.15 as used for western horse mackerel by the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (ICES, 1999b);

Mean weights at age in the catch and in the stock are a mean of years 1995-1997 of western horse mackerel (ICES, 1999b);

Maturity at age is the same as used by the Working Group over the period 1987-1997 for western horse mackerel (ICES, 1999b);

Assumed selection pattern: gradual increase in fishing mortality (F) up to age 4 and flat topped from age 4-15+; F of 0.01 for 0-group, 0.05 for 1-group, 0.10 for 2-group, 0.15 for 3-group, 0.20 for ages 4-15+ have been used to calculate the "true" age composition of the catch;

Fraction of F and M before spawning 0.45 (ICES, 1999b);

An average recruitment (R) of 4,000 million fish was assumed, which is the arithmetic mean of 0-group fish over the years 1983-1994, which does not include the extreme recruitment of the 1982 year class (ICES, 1999b);

The factor between largest and smallest recruitment affects the level of errors in the assessment. Therefore three different factors were used (factor 1, which implies that recruitment is constant and the factors 4 and 16). Recruitment values were randomly selected for a 40-year period between two recruitment levels that reflected the recruitment factor, while maintaining the average recruitment at 4,000 million fish.

These basic input values are listed in Table 1.

The true population numbers at age over a 40-year period were calculated up to a 20+ age group from annual recruitment, M and F at age. True SSB values were calculated for the last 12 years from true population numbers at age, maturity at age, mean weights at age in the spawning stock and fraction of F and M before spawning. The true catch in numbers at age were calculated up to a 20+ group over a 40-year period.

Converting true catch in numbers at age into catch in numbers at age that do include age reading errors

The normal distributions of age reading errors were applied to true catch in numbers at age data. Table 2 shows an example of age reading errors of CV=15% with bias. The catch in numbers at age that include age reading errors were calculated as follows. The proportions that are listed on the diagonal line in Table 2 are multiplied with the true catch in numbers at age of each particular age group and the sum of products is put into the age group that corresponds to "agreement". The shaded area shows what group of sum of products is put into the 15+ age group. The unshaded squares of age groups 15 – 19 have been reallocated to the younger age groups 10 - 14. This has been the correct way of applying age reading errors to a 15+ group.

The catches in tonnes, which were calculated from the catch in numbers at age that do contain age reading errors and the mean weights at age in the catch, were less than 1.5% percent lower than the true catch in tonnes based on the true catch in numbers at age. A correction factor has been applied to the catch in number data with age reading errors in order to correct for this small difference. In this way the sum of products (SOP) from the true catch in numbers at age and the catch in numbers at age that contain age reading errors became equal.

Stock assessment

Assessment of the artificial horse mackerel population was carried out by fitting an integrated catch-at-age model including a separable constraint over a ten-year period (Patterson and Melvin, 1996; Deriso *et al.*, 1985; Gudmundsson, 1986). The Integrated Catch Analysis (ICA) program (version 1.4) was used to evaluate the effect of age reading errors.

The reference F for separable constraint was at age 4. A flat-topped selection pattern was used as input, which implies that S to be fixed on the last age (15+) was taken as 1 (Table 1). Mean F was calculated over ages 5-14. An index file containing a 12 years time series of SSB values was used for tuning. The listed biomass values in the index file for tuning were regarded as absolute values.

4 RESULTS

Figure 5 shows the actual observed errors in age reading of otolith set K at the end of the 1999 Workshop. Two types of errors can be observed: a) precision: the variability increasing with age, and b) accuracy: the age of the older fish is underestimated (absolute bias).

The created normal distributions of age reading errors of CV=15% with bias (lower panel of Figure 4) are similar to the observed errors in age reading as shown in Figure 5. Some of the observed distributions are somewhat skewed.

Figure 6 shows the predicted percent agreement at age compared to observed percent agreement at age from otolith sets G and K (1999 Workshop). The percent agreement at each age can be predicted from the area under the normal curve, if age determinations are normally distributed about some true age. The observed percent agreement at age for age groups 3 – 9 appeared to be higher than predicted.

Figures 7–9 show the effect of the age reading errors on the assessment given in percentage over- and underestimation of recruitment, of SSB and of F over a 40-year period for recruitment factors of respectively 1 (constant recruitment), 4 and 16. Precision and precision combined with bias result in opposite effects on the estimation of recruitment, SSB and F. The effect of bias is highest when the precision is high (CV=5%). A low precision (CV=15%) combined with bias results in better estimates than high precision (CV=5%) combined with bias. If no bias occurs then a high precision (CV=5%) provides the best estimates of SSB and F. However, for the recruitment estimation it appears to be more complicated. Best estimates of recruitment are obtained for CV=5% and then for CV=5% with bias when recruitment is constant (recruitment factor 1). In the recent years (-12 – 0) the errors in the estimation of recruitment are similar for recruitment factors 1, 4 and 16. Recruitment is underestimated in the absence of bias (best estimate for CV=5%). Recruitment is overestimated in the presence of bias (CV=15% provides better estimates than lower CV's). But in the earlier years (-39 – -14), when the recruitment factor is 4 or 16, the recruitment estimates appear to become a lot more independent of bias. Precision compared to bias has a major impact on the accuracy of the recruitment estimate (Figure 8 and 9) in the earlier years. The worst recruitment estimates are obtained for CV=15% with and without bias. Better estimates are obtained for CV=10% with and without bias and the best estimates for CV=5% with and without bias. In many cases the options of CV's without bias provided worse recruitment estimates compared to CV's with bias.

It is remarkable that overestimation of recruitment, SSB and F in the last year(s) coincides with underestimation in the earlier years and vice versa. However, the switching point differs considerably for recruitment (-13 years) compared to SSB and F (-3 years).

In the case of constant recruitment the errors in recruitment, SSB and F become very stable prior to 20 years back calculation (-40 – -20 years). However, for recruitment factor 4 and even more so for recruitment factor 16 it becomes more difficult to estimate recruitment accurately in these earlier years:

Recruitment factor **1**	Recruitment between 0.1% and 0.3% overestimated, when CV=15% + bias;
Recruitment factor **4**	Recruitment between 29% underestimated and 109% overestimated, when CV=15% + bias;
Recruitment factor **16**	Recruitment between 36% underestimated and 211% overestimated, when CV=15% + bias.

Figure 10 shows the percentage under- and overestimation of the population at age in the last year (0) for the different age reading errors (CV of 5%, 10% and 15% with and without bias) and for the three different recruitment factors. The case of constant recruitment provides the clearest information on the effects of age reading errors on the estimation of the population at age. Bias causes highest overestimation in the younger age groups, which gradually decreases up to age 10, becomes an underestimation from age 11 onwards and the 15+ age group shows a sudden increase in the underestimation. The age reading errors including bias have the best agreement to the true population at age in the case of CV=15% with bias (much better agreement than CV=5% with bias). Precision errors in the absence of bias show the opposite effect, but do not show this sudden change for the 15+ age group. The age reading errors of CV=5% have the best agreement to the true population at age. For recruitment factors 4 and 16 it is less clear to recognise the above-described errors in the estimation of the population at age. This is because of the additional effect of overestimating weak year classes and underestimating strong year classes as also was observed in Figures 8 and 9.

Figure 11 shows the estimated selection patterns for the 10 year period of separable constraint for the different age reading errors (CV of 5%, 10% and 15% with and without bias) for three different recruitment factors (1, 4 and 16). The age reading errors, which do not include bias, provide fitted selection patterns that are closest to the true selection pattern. The best agreement is obtained in the case of CV=5%. However, if the age reading errors do include bias, the fitted selection patterns become dome shaped in contrast to the original flat-topped selection pattern. The highest selection is obtained at approximately age 7 or 8 (overestimation approximately 25%). There are nearly no differences in the selection patterns based on the three different recruitment factors.

Figure 12 shows an example of transfers of misageings to adjacent year classes and illustrates this difference between strong and weak year classes when applied age reading errors are CV=15% with bias. Strong year classes are considerably underestimated and weak year classes are overestimated even more.

5 DISCUSSION AND CONCLUSIONS

The extremely strong 1982 year class has been used to validate the age reading method for horse mackerel (Eltink and Kuiter, 1989 and ICES, 1999a). Furthermore otoliths of this year class have been used during the 1996 Otolith Exchange (Eltink, 1997) and at the 1999 Otolith Workshop (ICES, 1999a) to check and improve age reading techniques of age readers. At the end of the 1999 Otolith Workshop the results of the age readings of otolith set K provided information on precision, accuracy and absolute bias, which was achieved by experienced and inexperienced individual age readers and by all readers combined (ICES, 1999a). The observed bias could be taken as absolute bias, since the age readings were compared to 'actual' age (see for explanation of 'actual' age the introduction of this paper and ICES, 1999a). The effects of age reading errors on the assessment can only be evaluated, if information on precision and absolute bias available is.

The term accuracy is defined as the closeness of a measured or computed value to its true value. For a measurement technique that is free of bias, precision implies accuracy (from Kalish *et al.*, 1995). Accuracy is a matter of degree and measures how close an estimated age is likely to be to the true age (Francis, 1995). Absolute bias is defined as a systematical over- or underestimation of age compared to the true age. The accuracy of an age reading technique of an individual age reader or a group of readers is best described as absolute bias by age. The absolute bias can be calculated for each 'actual' age from the mean age recorded minus 'actual' age. The absolute bias can be an overestimation of age, if the estimated age is larger than the 'actual' age or an underestimation of age, if the estimated age is smaller than the 'actual' age.

Several authors described the dangers of using percent agreement as measure of precision (Beamish and Fournier, 1981; Chang, 1982, Kimura and Lyons, 1991; Campana *et al.*, 1995), because this index is independent of age. The traditional index of precision in ageing studies, percent agreement, is gradually falling out of favour, because percent agreement may vary substantially among ages (Campana *et al.*, 1995). The percent agreement is very dependent on the age composition of a sample, because it is easier to achieve a high percent agreement in a sample with many young fish compared to a sample with many old fish. Therefore, the percent agreement is only comparable at an age level within a species. An index of average percent error (APE) is a better estimate of precision of age determinations, because it is not independent of the age of a fish (Beamish and Fournier, 1981). The coefficient of variation (CV), which is also not independent of the age, is regarded as a robust measure of precision by Chang (1982), Kimura and Lyons (1991) and Campana *et al.* (1995).

Kimura and Lyons (1991) presented a hypothesis that age determinations are normally distributed with a constant coefficient of variation over relatively wide age ranges. Their modeling results indicated that estimated percentage agreements were consistent with this hypothesis. For the 1999 Otolith Workshop this hypothesis was also accepted. For each age reader a weighted mean of the CV's at age was estimated from the age reading results of the Workshop (ICES, 1999a). Such a CV by reader was intended to indicate his/her precision in age reading compared to the other age readers and to the whole group. The mean CV over all ages was assumed to be independent of the age composition of the sample, if the CV would be more or less constant over a wide age range. However, the standard deviations at age obtained from age reading results from otolith sets G and K, which both achieved a mean CV of 15% for all readers combined, do not indicate that CV is constant over all ages. The standard deviations increased non-linearly from 0.21 at age 1 to 1.32 at age 13 (Figure 1), corresponding to a nearly linear decrease of the CV from 21% for age 1 to 10% for age 13. The relatively higher CV's for these younger ages indicate that age readers probably have more problems in determining the age of younger fish. This might possibly be due to the occurrence of false rings during the juvenile stages and probably because the juvenile growth zones, which include false rings, become easier to interpret when annual growth zones as adult are present.

In this study the term precision is defined as the variability of the age readings by 'actual' age by individual age reader and is expressed as CV at age (stdev/mean age recorded). The mean CV over all age groups is the mean CV weighted by the number of age readings by age group. This mean CV of 15% for all age readers appears quite high taking into account that the mean CV's of the individual readers ranged from 8% to only 15%. The CV, which is a measure of precision, is artificially inflated by any bias between age readers. This effect was also observed by Campana *et al.* (1995).

Age readings become less precise with increasing age resulting in a spread over adjacent year classes. The only reason the ages would not be smoothed is reader-bias, which occurs if dominant or weak year classes are being anticipated by the age-reader and are taken into account when assigning the ages. This reader-bias is not taken into account in this evaluation. The possibility of reader-bias has been excluded in the otolith sets of the 1996 Otolith Exchange (Eltink, 1997) and the 1999 Otolith Workshop (1999a) by taking roughly the same number of otoliths for each age group in each otolith set.

In this paper the observed errors in precision, which increase with age, are converted into normal distributions by using the observed information on standard deviation at age. The observed absolute bias at age is included in these normal distributions by shifting these distributions accordingly on the x-axis (compare figures 3 and 4). The question can be raised, whether these constructed distributions of age reading errors reflect the actual distributions of age reading errors. The observed distributions from otolith set K appeared to be somewhat skewed (compare lower panel of Figure 4 with Figure 5). Figure 6 shows the predicted percent agreement at age based on the smoothed standard deviation curve from Figure 1. This predicted percent agreement at age has been compared with the actual percent agreement at age as achieved for otolith sets G and K. The predicted percent agreement at age is lower than the actually achieved ones in set G and K for ages 3-9. The constructed normal distributions of the ageing errors (Figures 3 and 4) have been used in the evaluations, because the observed differences were regarded to be too small to correct for these.

The observed recruitment as 0-group of year classes 1983-1995 as given in the report of the Working Group on the Assessment of Mackerel, Horse Mackerel, Sardine and Anchovy (ICES, 1999b) appeared to be randomly distributed. Therefore, recruitment was chosen randomly between two levels of recruitment, while taking into account that the mean recruitment should be 4,000 million fish and that the ratio between the two levels should reflect the recruitment factors 4 or 16. The recruitment factor could not be estimated from observed recruitment strength, because the strength of strong year classes is underestimated and the strength of weak year classes is heavily overestimated. Therefore, arbitrary recruitment factors of 4 and 16 were chosen.

If a reader-bias had been taken into account in this evaluation, this would have reduced the effects of the age reading errors, because the spread in the age readings would have been reduced.

Figures 7–10 show that the effect of bias on the assessment is best compensated by a low precision (high CV of 15%). The opposite effects of both types of age reading errors cause this compensation. The precision errors cause an overestimation of age, because younger year classes are more abundant causing relatively more fish to be transferred from younger year classes to older ones than vice versa. Underestimation of the older ages (bias) has the opposite effect, because it causes relatively old fish to be transferred to younger year classes. It should be noted that if bias would be an overestimation of the older ages than precision and bias do not have an opposite effect, but would even increase each others effect.

Recruitment is estimated close to the true strength, if recruitment is constant. But when recruitment is more variable, weak year classes will be more and more overestimated and strong year classes more and more underestimated. This is caused by the following phenomenon in the ageing process. If adjacent year classes differ considerably in absolute strength, a strong year class will transfer a lot more fish to a weak year class than vice versa. This is because the ageings are not precise and certain proportions of a year class are transferred to the neighbouring year classes. The transfer can be equal in proportion from one year class to the other and vice versa, but in absolute numbers these transfers can differ considerably. Figure 12 shows an example of transfers of misageings to adjacent year classes because of age reading errors (CV=15% with bias) and illustrates the difference between strong and weak year classes.

Age reading errors as were observed at the end of the 1999 Workshop (CV=15% with bias) have the following effects on the assessment of horse mackerel. Assumptions made in this evaluation are: recruitment factor is approximately 16 and reader-bias is not taken into account:

- Below average recruitment might be over 200% overestimated and above average recruitment up to 35% underestimated. In addition the recruitment of the most recent years will be overestimated (gradually increasing up to 20% in the last year). The assessment will provide only very smoothed recruitment estimates and the difference between highest and lowest observed recruitment might be 5 times higher.

- F will be 1-9% overestimated except in the last two or three years, when it might be slightly underestimated.

- SSB will be 0-7% underestimated except in the last two or three years, when it might be slightly overestimated.

- The population at age in the last year will show the highest overestimation in the younger age groups, which gradually decreases up to age 10, becomes an underestimation from age 11 onwards and the 15+ age group shows a sudden increase in the underestimation. There is an additional effect of overestimating weak year classes and underestimating strong year classes.

- The fitted selection pattern in the last year will become dome shaped because of the bias. The highest selection is obtained at approximately age 7 or 8 (approximately 20-25% overestimation).

It is a first priority that the bias in age reading is reduced and in addition the precision is increased (CV lower). Improving the precision considerably without reducing the bias would result in an even worse assessment, because precision errors have a compensating effect on the bias error. In future, if it appears to be difficult to reduce the bias in the age readings of the older ages, it might be worth considering reducing the 15+ group to i.e. a 8+ group. This would have as disadvantage that a lot more fish would be aggregated in the 8+ group (especially if an extremely strong year class would enter the fishery again).

For assessment purposes it would be very interesting to correct age compositions, which include age reading errors. A true age composition can be converted into an age composition that includes age reading errors, but unfortunately the reverse is impossible, because the year class strength should be known for this conversion.

The effects of observed age reading errors on the assessment of horse mackerel do not explain the problems in assessing this stock (ICES, 1999b). Factors such as the assumption of natural mortality, proportion mature at age, SSB estimates from egg surveys, age sampling by area/period, raising of age compositions to international catches, etc. are likely to have a larger impact on the assessment.

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Table 1 The general input for the creation of three artificial populations over a 40-year period based on three different recruitments.

Age	Selection pattern	F-pattern	M	mean 1995-1997 STOCK weight at age (kg)	mean 1995-1997 CATCH weight at age (kg)	Maturity at age
0	0.05	0.01	0.15	0.000	0.015	0.00
1	0.25	0.05	0.15	0.000	0.045	0.00
2	0.50	0.10	0.15	0.050	0.068	0.10
3	0.75	0.15	0.15	0.094	0.085	0.40
4	1.00	0.20	0.15	0.122	0.108	0.60
5	1.00	0.20	0.15	0.122	0.136	0.80
6	1.00	0.20	0.15	0.149	0.155	1.00
7	1.00	0.20	0.15	0.170	0.175	1.00
8	1.00	0.20	0.15	0.183	0.184	1.00
9	1.00	0.20	0.15	0.191	0.200	1.00
10	1.00	0.20	0.15	0.202	0.215	1.00
11	1.00	0.20	0.15	0.201	0.228	1.00
12	1.00	0.20	0.15	0.222	0.231	1.00
13	1.00	0.20	0.15	0.223	0.249	1.00
14	1.00	0.20	0.15	0.247	0.273	1.00
15	1.00	0.20	0.15	0.285	0.306	1.00
16	1.00	0.20	0.15	0.285	0.306	1.00
17	1.00	0.20	0.15	0.285	0.306	1.00
18	1.00	0.20	0.15	0.285	0.306	1.00
19	1.00	0.20	0.15	0.285	0.306	1.00
20+	1.00	0.20	0.15	0.285	0.306	1.00

Fraction of F and M before spawning =	0.45

Years backwards	Recruitment in '000 millions Recruitment factor 1	4	16
-39	4000	4625	4214
-38	4000	1610	3457
-37	4000	5732	1189
-36	4000	2169	1296
-35	4000	4052	4854
-34	4000	6370	1655
-33	4000	5422	468
-32	4000	4850	2284
-31	4000	4635	3211
-30	4000	5045	4344
-29	4000	2374	1069
-28	4000	5734	6066
-27	4000	1671	5782
-26	4000	5478	3323
-25	4000	5383	6912
-24	4000	4763	2464
-23	4000	3115	3897
-22	4000	3120	1104
-21	4000	5367	4050
-20	4000	1592	7350
-19	4000	4485	7488
-18	4000	2270	5357
-17	4000	4323	3967
-16	4000	1608	4334
-15	4000	2366	4207
-14	4000	1993	7013
-13	4000	6233	4882
-12	4000	4765	3216
-11	4000	3575	4549
-10	4000	5166	5820
-9	4000	5578	5519
-8	4000	4327	1583
-7	4000	5590	1406
-6	4000	1829	5592
-5	4000	6092	7071
-4	4000	4028	1046
-3	4000	2200	6551
-2	4000	3433	3285
-1	4000	2249	3236
0	4000	4770	4871
Average	**4000**	**4000**	**4000**
Minimum	**4000**	**1592**	**468**
Maximum	**4000**	**6370**	**7488**

Table 2 The normal distributions by age group of the age reading errors corresponding to a CV of 15% with bias.
An example of the calculation of the catch in numbers at age that contain age reading errros: the bold proportions listed below are multiplied with the true catch in numbers at age of each particular age group and then the sum of all products is put in the age group that corresponds to "agreement". The shaded area (bold italics) shows what group of sum of products is put into the 15+ age group.

	AGE READING ERRORS: CV=15% with bias										
Age group	=<-5	-4	-3	-2	-1	Agreement	+1	+2	+3	+4	+5>=	TOTAL
0	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	1.000
1	0.000	0.000	0.000	0.000	0.009	0.983	0.009	0.000	0.000	0.000	0.000	1.000
2	0.000	0.000	0.000	0.000	0.100	0.800	0.100	0.000	0.000	0.000	0.000	1.000
3	0.000	0.000	0.000	0.003	0.175	0.646	0.175	0.003	0.000	0.000	**0.000**	1.000
4	0.000	0.000	0.000	0.014	0.217	0.538	0.217	0.014	0.000	**0.000**	0.000	1.000
5	0.000	0.000	0.001	0.033	0.237	0.458	0.237	0.033	**0.001**	0.000	0.000	1.000
6	0.000	0.000	0.004	0.050	0.242	0.409	0.242	**0.050**	0.004	0.000	0.000	1.000
7	0.000	0.001	0.010	0.083	0.271	0.369	**0.211**	0.050	0.005	0.000	0.000	1.000
8	0.000	0.002	0.021	0.114	0.286	**0.337**	0.186	0.048	0.006	0.000	0.000	1.000
9	0.000	0.004	0.035	0.142	**0.294**	0.308	0.165	0.045	0.006	0.000	0.000	1.000
10	0.001	0.008	0.050	**0.167**	0.298	0.285	0.146	0.040	0.006	0.000	***0.000***	1.000
11	0.001	0.012	**0.065**	0.188	0.301	0.265	0.128	0.034	0.005	***0.000***	***0.000***	1.000
12	0.002	**0.018**	0.081	0.208	0.300	0.245	0.113	0.029	***0.004***	***0.000***	***0.000***	1.000
13	**0.004**	0.025	0.099	0.225	0.295	0.225	0.099	***0.025***	***0.004***	***0.000***	***0.000***	1.000
14	0.006	0.034	0.117	0.238	0.287	0.205	***0.087***	***0.022***	***0.003***	***0.000***	***0.000***	1.000
15	0.010	0.044	0.135	0.249	0.277	***0.187***	***0.076***	***0.019***	***0.003***	***0.000***	***0.000***	1.000
16	0.015	0.056	0.153	0.256	***0.265***	***0.169***	***0.067***	***0.016***	***0.002***	***0.000***	***0.000***	1.000
17	0.021	0.069	0.169	***0.260***	***0.252***	***0.153***	***0.059***	***0.014***	***0.002***	***0.000***	***0.000***	1.000
18	0.029	0.083	***0.184***	***0.261***	***0.238***	***0.138***	***0.052***	***0.012***	***0.002***	***0.000***	***0.000***	1.000
19	0.039	***0.098***	***0.197***	***0.260***	***0.223***	***0.125***	***0.045***	***0.011***	***0.002***	***0.000***	***0.000***	1.000
20	***0.051***	***0.112***	***0.208***	***0.256***	***0.208***	***0.112***	***0.040***	***0.009***	***0.001***	***0.000***	***0.000***	1.000

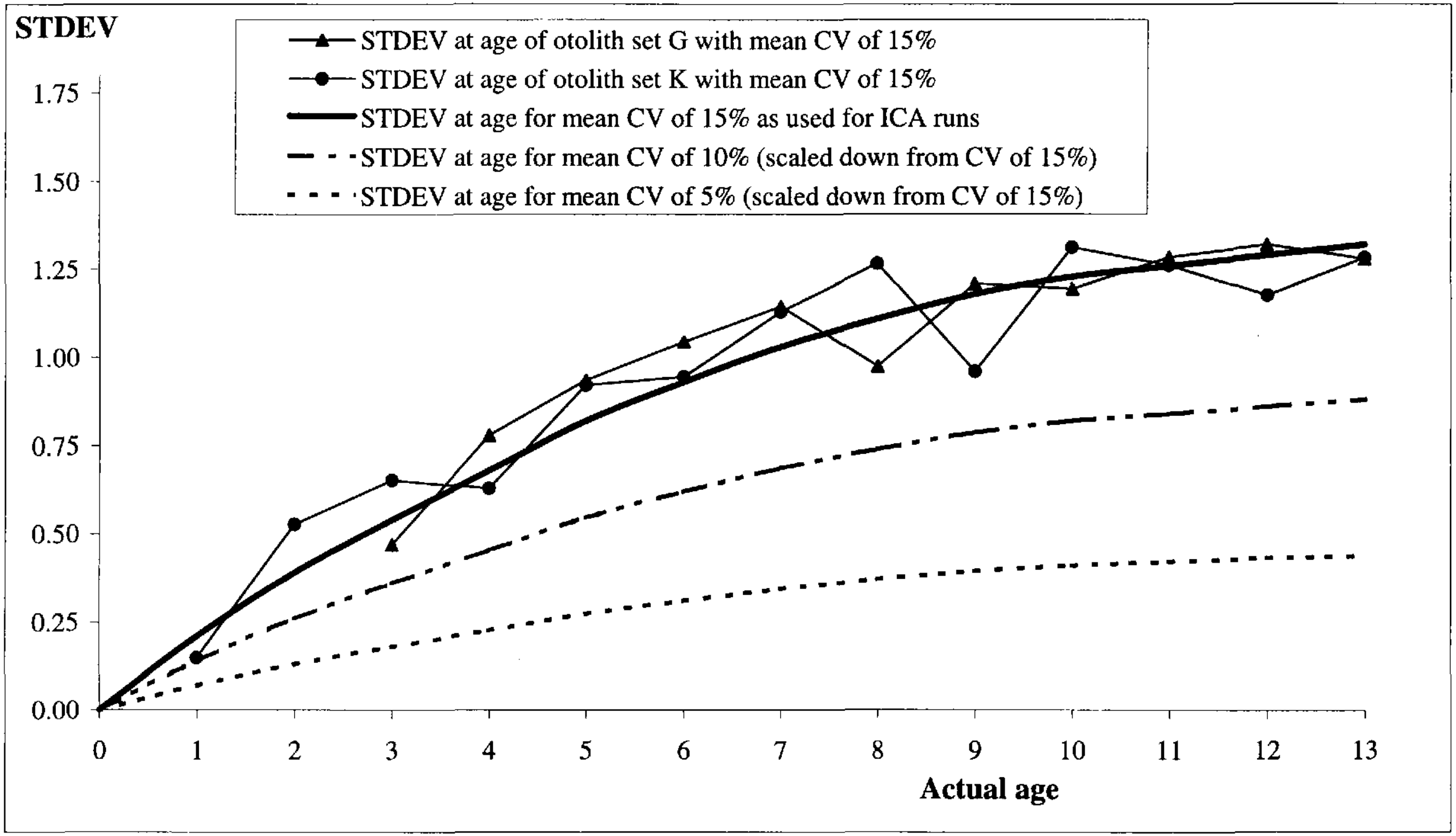

Figure 1 The standard deviations (STDEV) at age, which are necessary to create normal distributions of age reading errors, were obtained from a fit to the STDEV's from the age reading comparisons of otolith sets G and K from the 1999 Otolith Workshop taking into account that the mean CV over ages 1-13 remains 15%. The two broken lines are scaled down to correspond a precision in the age reading of CV=10% and CV=5%.

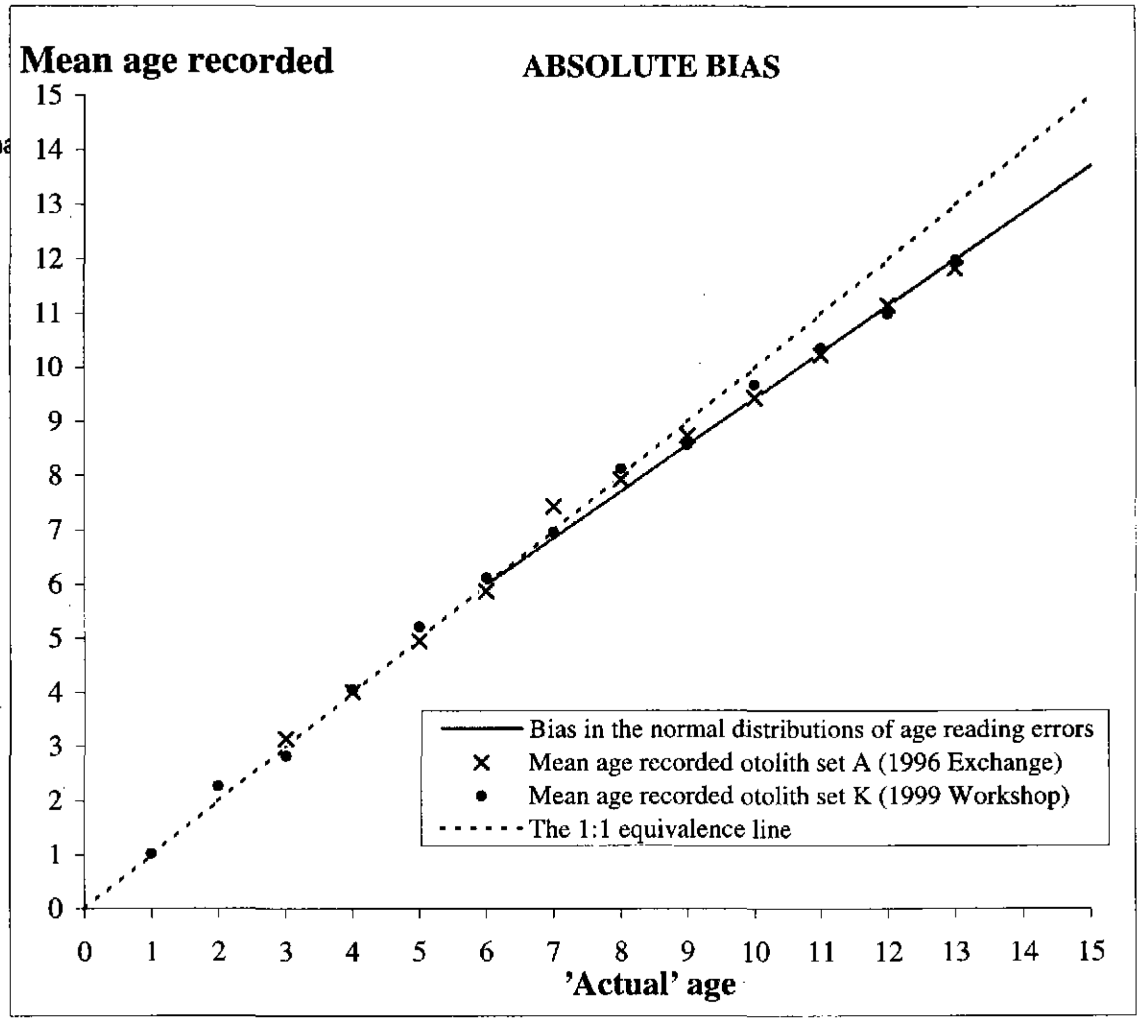

Figure 2 The absolute bias, which is included in the normal distributions of the age reading errors, is compared to the mean age recorded from otolith set K from the 1999 Otolith Workshop and to the mean age recorded from otolith set A from the 1996 Otolith Exchange. During the 1999 Workshop no improvement was made regarding the reduction of bias as observed in the 1996 Otolith Exchange.

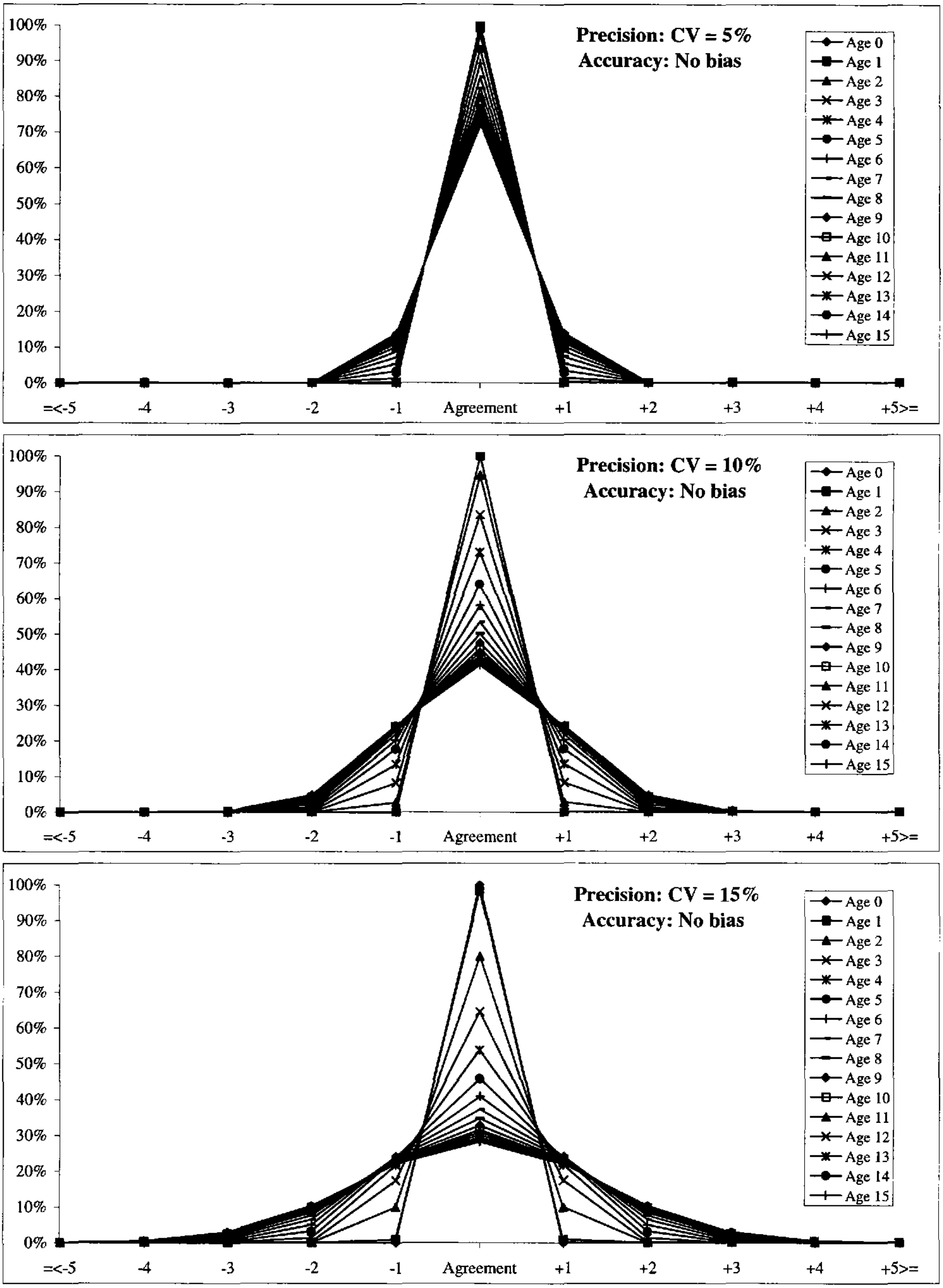

Figure 3 The normal distributions of the age reading errors based on a mean coefficient of variation of 5% (upper panel), 10% (middle panel) and 15% (lower panel). No absolute bias was included in these age reading errors.

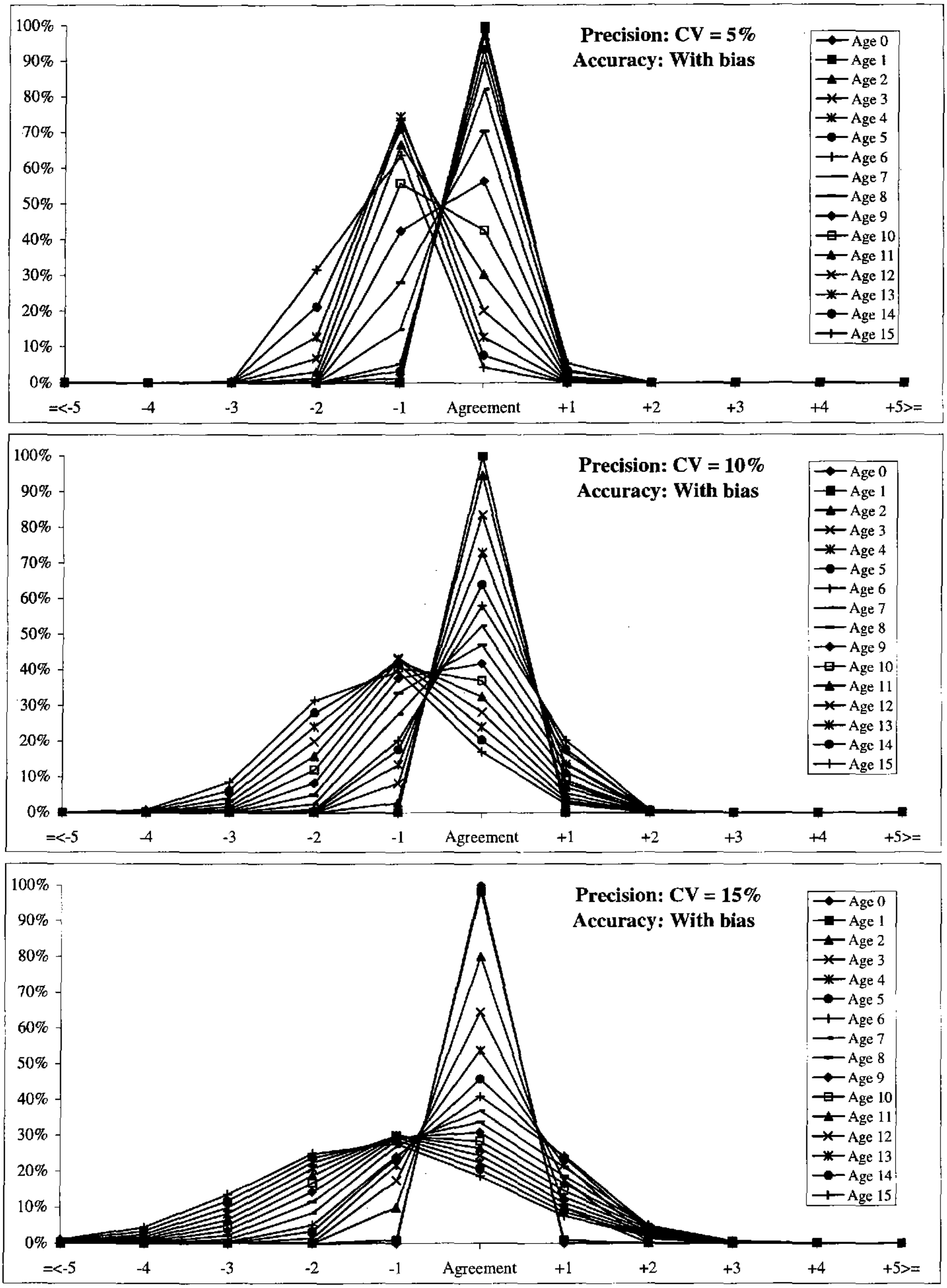

Figure 4 The normal distributions of the age reading errors based on a mean coefficient of variation of 5% (upper panel), 10% (middle panel) and 15% (lower panel). An absolute bias was included in the age reading errors, which starts at age 7 and gradually increases (1 year underestimation at age 13).

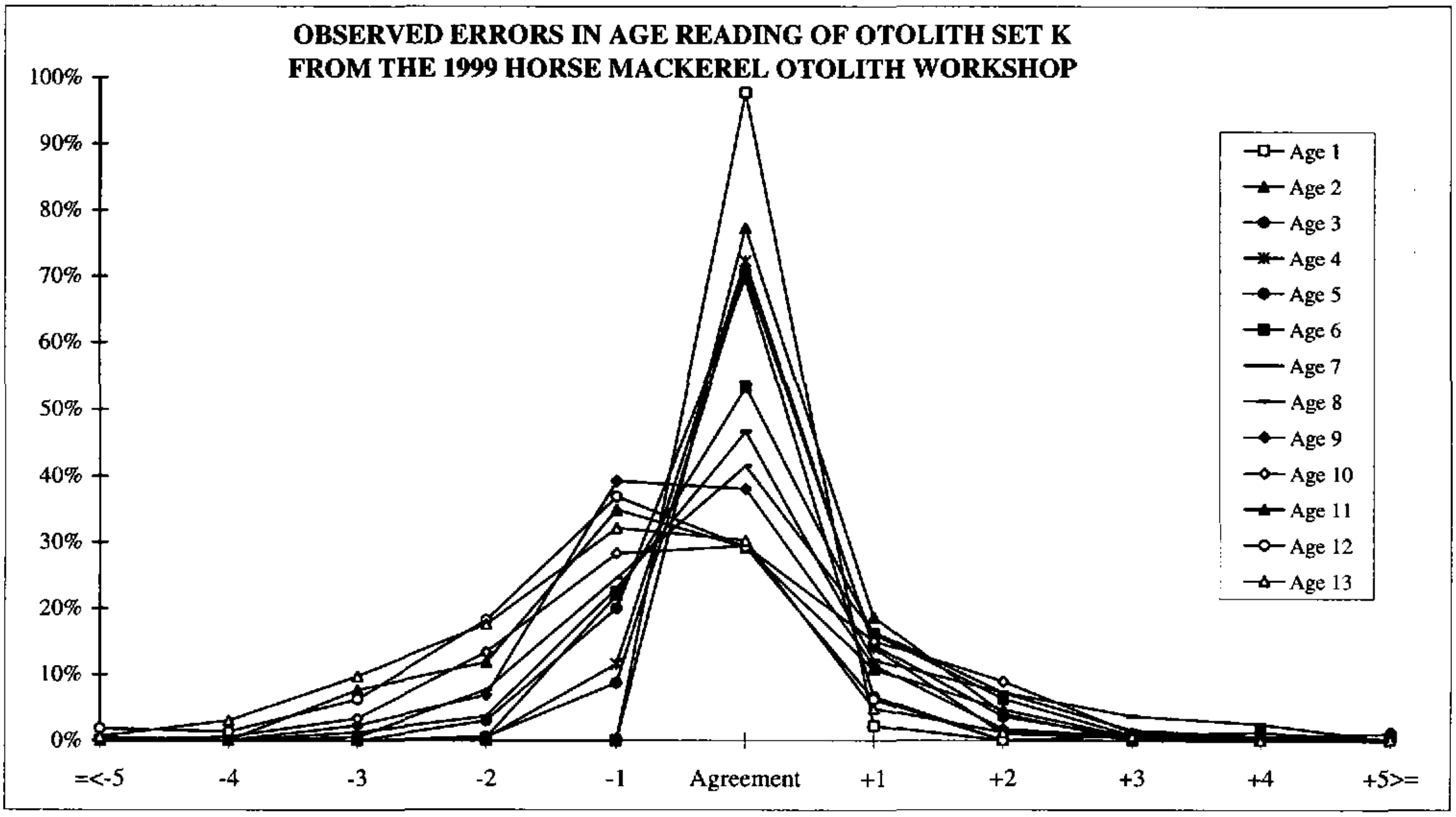

Figure 5 The observed errors in age reading of otolith set K at the end of the 1999 Otolith Workshop. The precision error is indicated by the spread of the age readings and the accuracy error by the shift of the distributions.

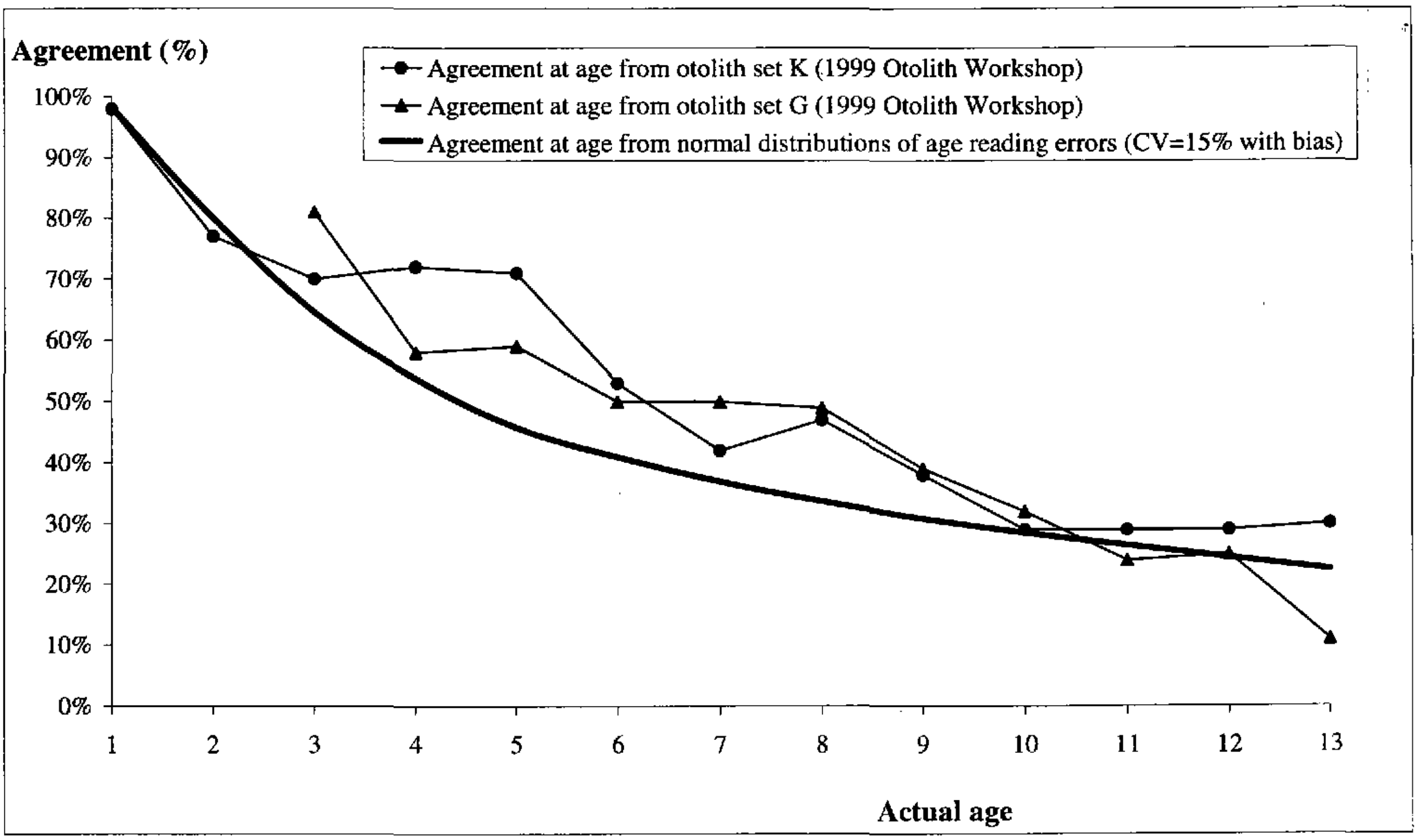

Figure 6 The agreement at age from the age reading comparisons of otolith sets G and K from the 1999 Otolith Workshop is compared to the agreement at age as estimated from the normal distributions of age reading errors based on CV=15% with bias.

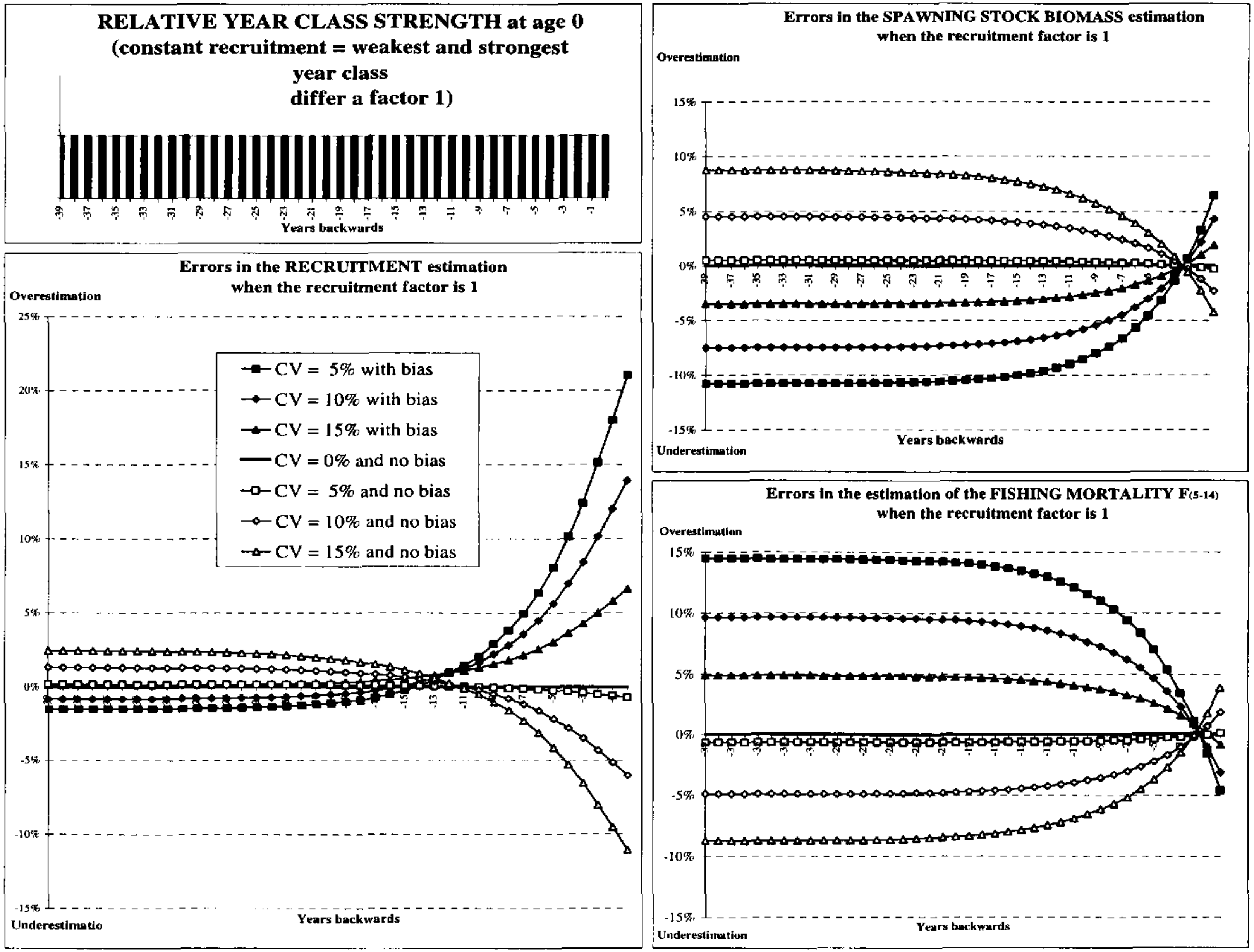

Figure 7 Effect of age reading errors on the assessement of horse mackerel when the recruitment factor is 1, which corresponds to cor
Upper left panel: Input of constant recruitment for the calculation of the true population at age and the true catch in numbers
Lower left panel: Errors in the estimation of recruitment, when age reading errors occur in the catch in number data.
Upper right panel: Errors in the estimation of spawning stock biomass, when age reading errors occur in the catch in number
Lower right panel: Errors in the estimation of fishing mortality, when age reading errors occur in the catch in number data.

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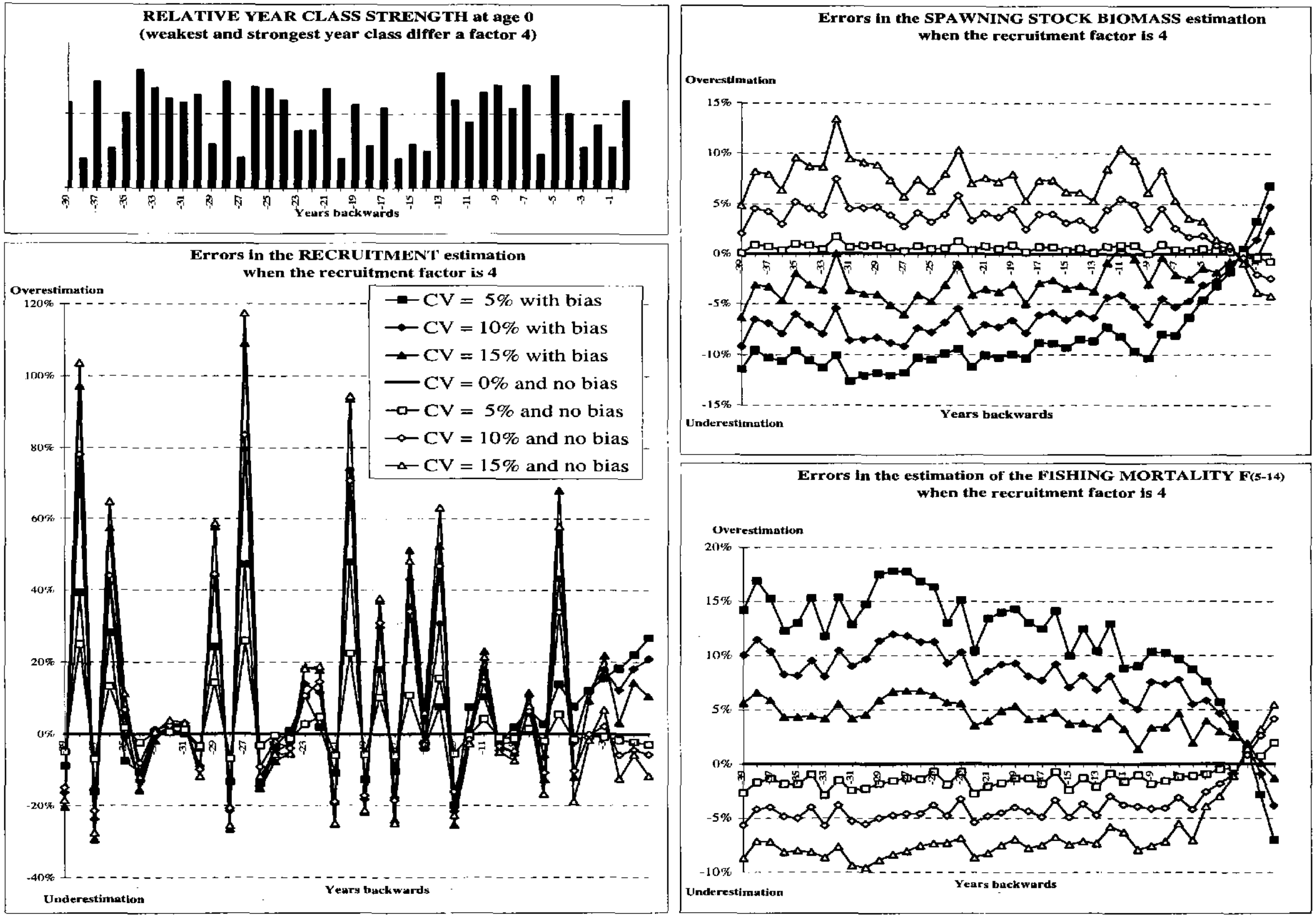

Figure 8 Effect of age reading errors on the assessement of horse mackerel when the recruitment factor is 4.
Upper left panel: Input of recruitment for the calculation of the true population at age and the true catch in numbers at age.
Lower left panel: Errors in the estimation of recruitment, when age reading errors occur in the catch in number data.
Upper right panel: Errors in the estimation of spawning stock biomass, when age reading errors occur in the catch in number data.
Lower right panel: Errors in the estimation of fishing mortality, when age reading errors occur in the catch in number data.

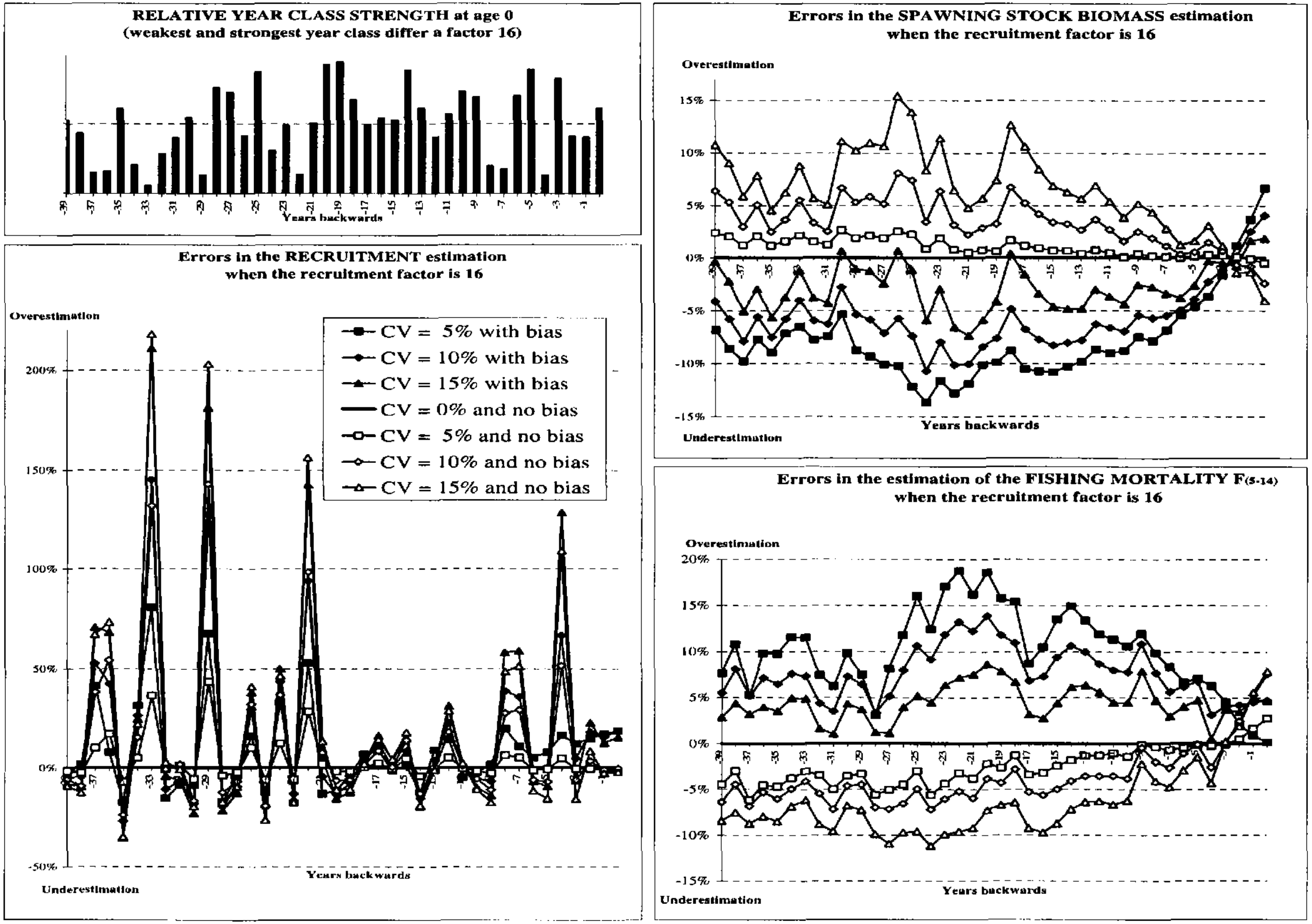

Figure 9 Effect of age reading errors on the assessement of horse mackerel when the recruitment factor is 16.
Upper left panel: Input of recruitment for the calculation of the true population at age and the true catch in numbers at age.
Lower left panel: Errors in the estimation of recruitment, when age reading errors occur in the catch in number data.
Upper right panel: Errors in the estimation of spawning stock biomass, when age reading errors occur in the catch in number data.
Lower right panel: Errors in the estimation of fishing mortality, when age reading errors occur in the catch in number data.

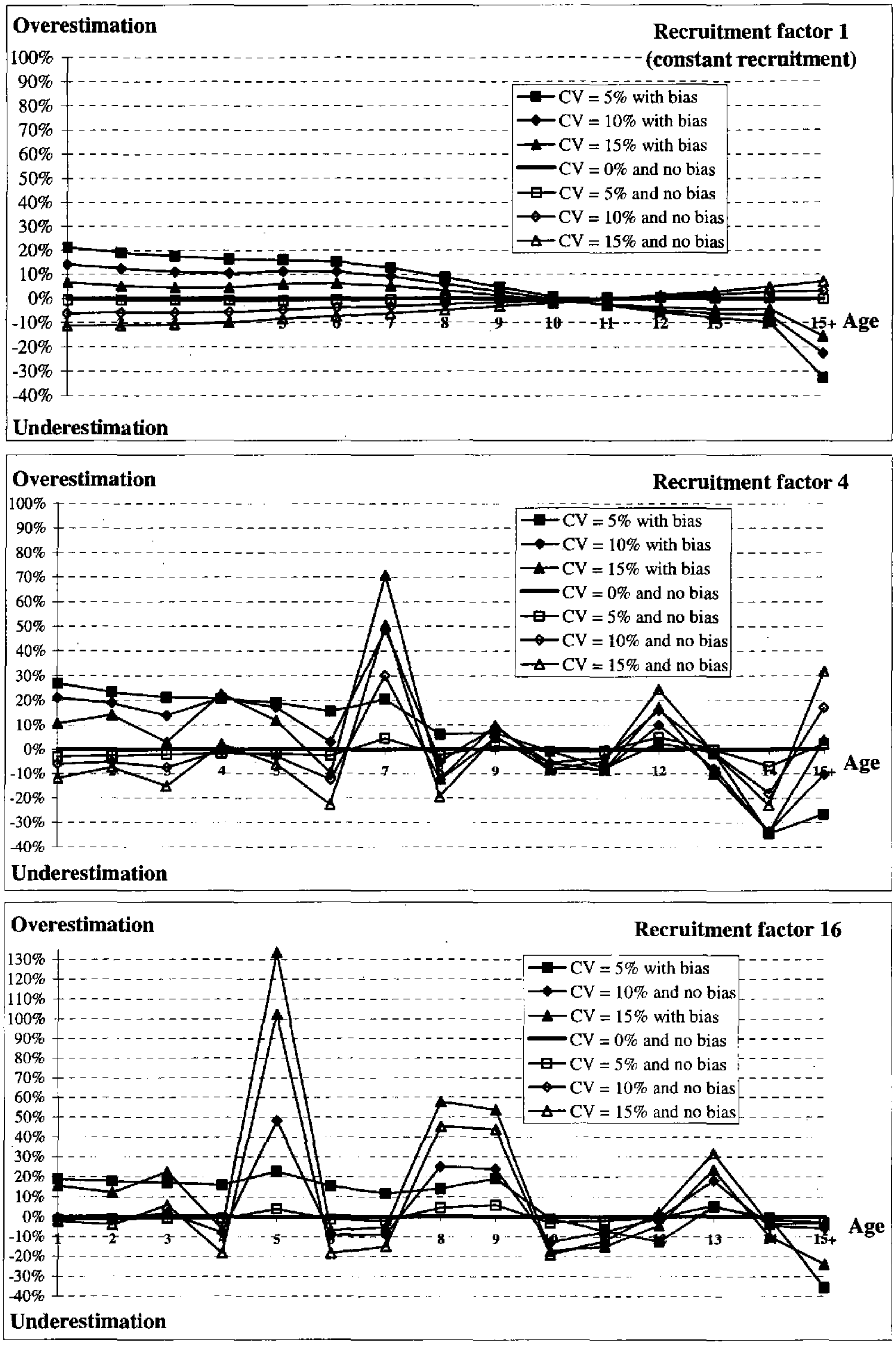

Figure 10 Errors in the estimation of the population at age in the last year for the different age reading errors (CV of 5%, 10%, 15% with and without bias) when the recruitment factors are respectively 1 (upper panel), 4 (middle panel) and 16 (lower panel). The thick line represents the line with no age reading errors.

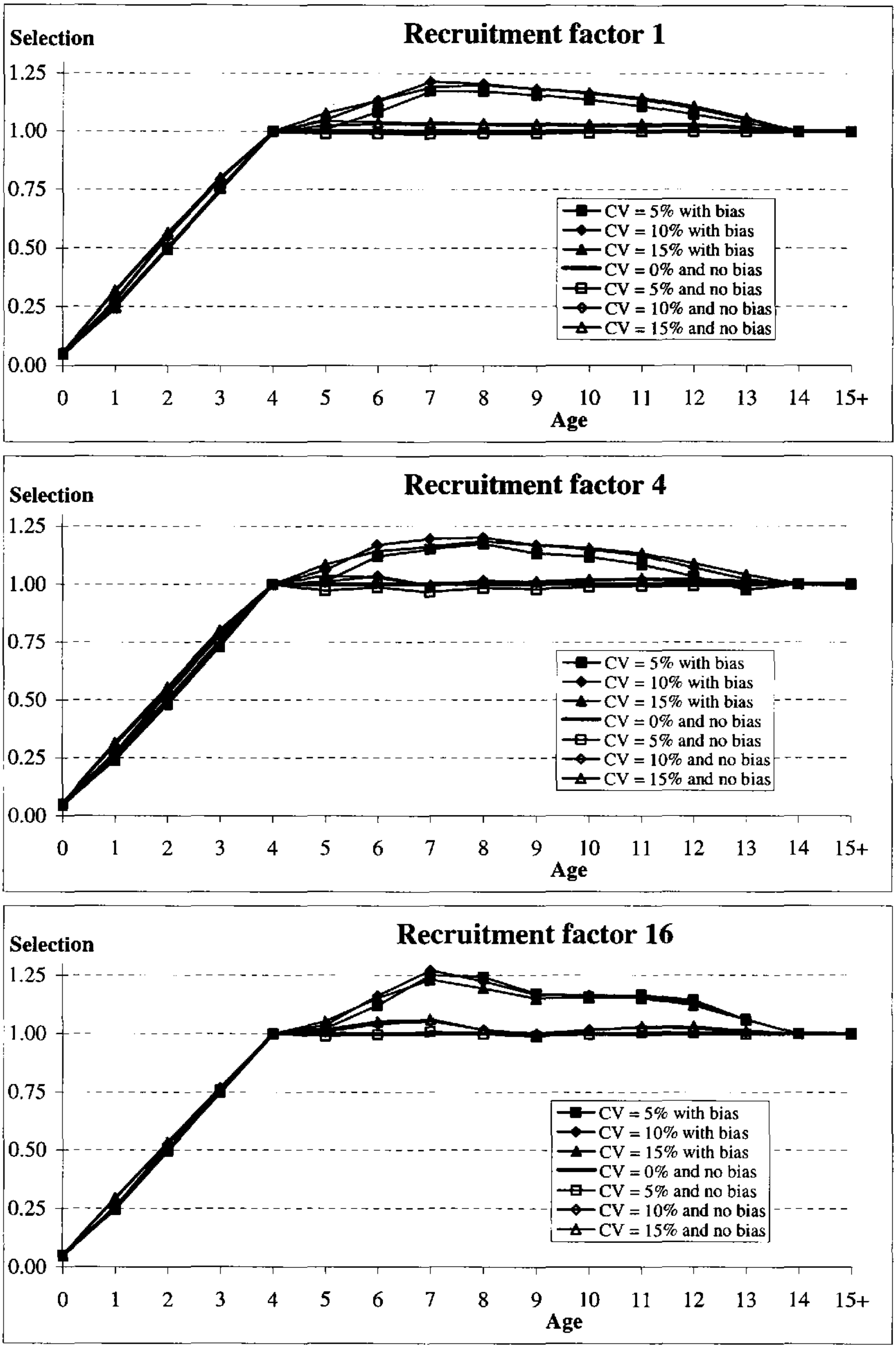

Figure 11 Estimated selection patterns for the 10 year period of separable constraint for the different different age reading errors (CV of 5%, 10%, 15% with and without bias) when the recruitment factors are respectively 1 (upper panel), 4 (middle panel) and 16 (lower panel) The thick line is the selection pattern, if no age reading errors occur.

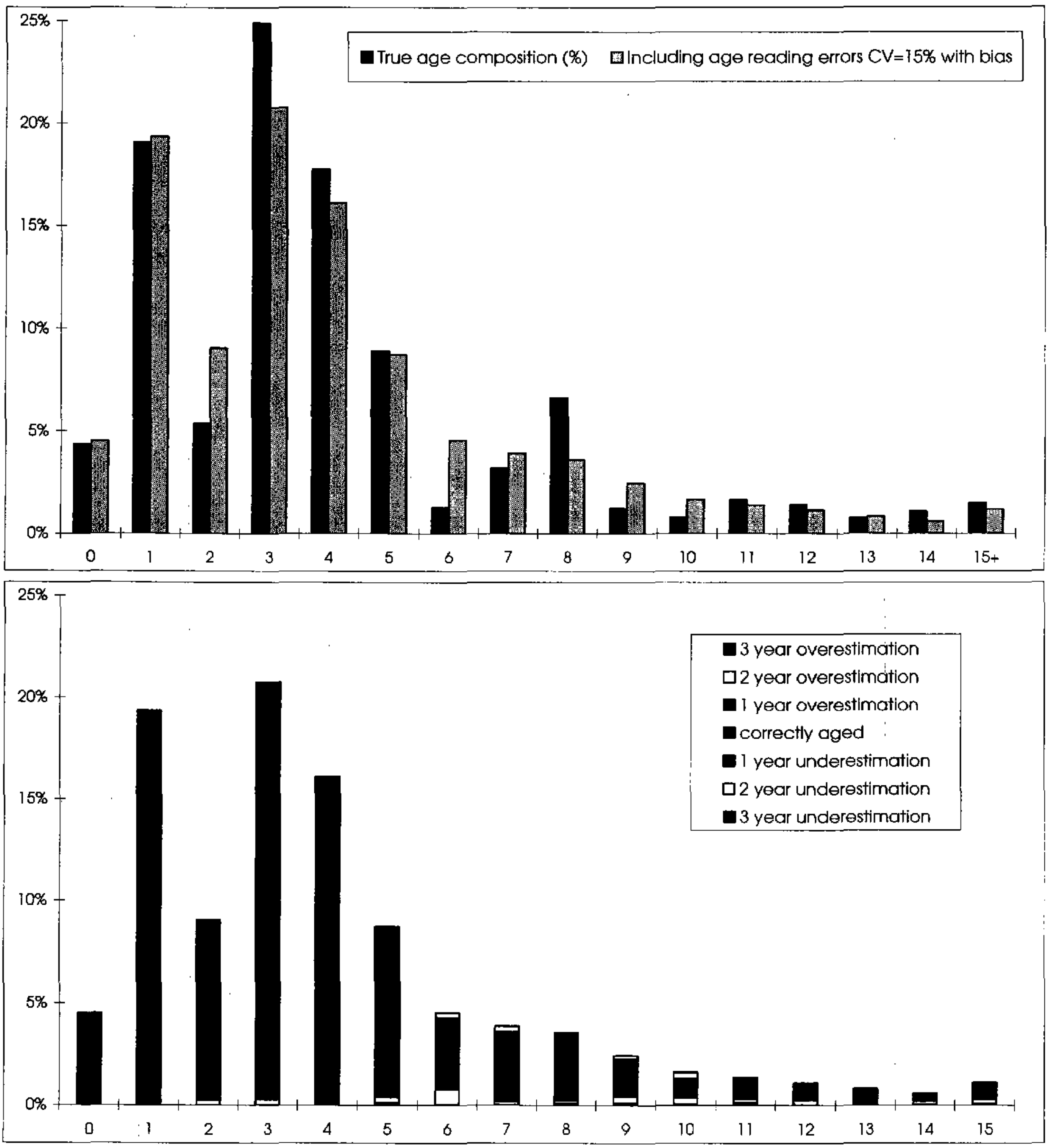

Figure 12 Upper panel: a true age compositon together with its converted age composition that includes the age reading errors as observed at the end of the 1999 Horse Mackerel Otolith Workshop (CV=15%+bias). Lower panel: the same age composition that includes the age reading errors, but now indicating what part was correctly aged and what parts came from misageings of adjacent year classes.